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EVALUATION OF DATA UTILITY FOR EARTH SCIENCES FROM METHODICAL POINT OF VIEW

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REPORT STANDARD TITLE PAGE

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Co-investigators: Sven Behrens, Karl Erik Bergsten, Karna Lidmar-Bergström, Sven Lindqvist, Jan Mattsson and Siw Nordström

15. Abstract

During the reporting period the following topics have been treated:

1. The physiography of Scania and Seeland.
2. Morphological features in the region of the Great Swedish Lakes.
3. Tectonic structures in south-western Sweden.
4. Recording of coast line and depth conditions in a district of southern Sweden.
5. Cloud formation in coastal areas.
6. Mesoscale cloud patterns and structures.
7. The break-up situation in a lake district of south-western Sweden.

Preprints are enclosed.

a. Title: EVALUATION OF DATA UTILITY FOR EARTH SCIENCES FROM METHODICAL POINT OF VIEW

SR No. 306

b. GSFC ID No. of P.I.: FO 426

c. Statement and explanation of any problem that are impeding the progress of the investigation:

1. For the geomorphological and geological studies inside our project the images of last summer (1973) have proven very usable. Unfortunately, however, the colour products ordered in a data request of September 30, 1973 have not yet arrived.

2. For the comparative studies of seasonal differences in the ground and vegetation surfaces of our test areas we are still missing good coverages from autumn (September - November) and from spring (April - Mai).

3. For the winter situation (November - February) no imagery exists that could be used for the evaluation of snow and sea-ice distribution.

d. Accomplishments during the reporting period and those planned for the next reporting period.

The studies listed below have been accomplished:

1. Behrens,S.: Analysis of the physiography of Scania and Seeland interpreted in ERTS-images.
2. Bergsten,K.E.: Some morphological features in the region of the Great Swedish Lakes.
3. Lidmar-Bergström, Karna: Tectonic analysis of south-western Sweden by means of ERTS images.
4. Lindqvist,S.: Studies of cloud formation in coastal areas by means of ERTS-1 imagery.

5. Mattsson,J.: Cloud studies based on ERTS-1 pictures.

6. Nordström, Siw: Recording of coast line and depth conditions at the Falsterbo peninsula, southern Sweden.

7. Svensson,H.: Break up of lake ice observed in ERTS-1 images from south-western Sweden.

The next reporting period will be devoted to:

1. Studies of the possibilities for land-use mapping in regional planning.

2. Detection of smoke plumes and distribution of aerosol content.

3. Water pollution and current patterns in the Baltic.

4. Surveying marginal deposits and recession lines of the last glaciation in southern Sweden.

e. Discussion of significant results and their relationship to practical applications or operational problems:

Cf the conclusions in the reports enclosed.

f. Listing of published articles, and/or papers, preprints and in house reports that were released during the reporting period:

Mattsson, J.: Molnstudier med bilder från ERTS-1. Rapp. o. Not. Lunds Univ. Naturgeogr. Inst. Nr. 19. 1973.

ANALYSIS OF THE PHYSIOGRAPHY OF SCANIA AND SEALAND INTERPRETED BY MEANS OF ERTS-IMAGES.

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Abstract: Among the elements most significant in synthesizing the physiography of a landscape, coast line, vegetation and surface-drainage system are reproduced very distinctly on the satellite pictures, while the relief is indicated mainly by the orientation of the lakes, by shadow effects and vegetation pattern. However, the purpose of the examination of the ERTS-images of March 9, 1972, was primarily to find actual morphological lineaments and to compare their direction with those of the oriented bedrock elements, such as the structure and joint systems.

Certain frequently occurring directions in the geometric shape of the land contour and in the relief of the land surface appear in the course of the examination of the pictures. Thus, three different directions can be traced and related to the character of the bedrock surface and to the structure and tectonic elements of the bedrock. The last two properties chiefly apply to the Precambrian region of northern Scania, where the schistosity of the gneiss, onstituted as s-planes in the N-S direction, and joint systems in NW-SE coincide with the morphological lineaments. Accordingly, it can be stated that the former have given rise to the latter.

Introduction

The physical landscape, as well as the anthropogenic, is made up of different elements that may sometimes be arranged in real patterns. As a rule, a certain perspective is required in order to be able to observe such patterns in the physical landscape or in the pictorial presentation of the landscape. Therefore, it is presumable that pictures taken from a large altitude will contain valuable information in this respect.

Those elements which together constitute the image of the physical landscape are in the first place, relief of theland surface, drainage network, vegetation and the borderline between land and sea.
At the examination of images of Sealand and western Scania these elements and their spatial arrangement have been particularly studied in order to find dominating morphological lines, so called lineaments in the landscape and, if possible, whole spatial patterns. By comparing the clearly observed or more vaguely indicated linear and surface patterns with the already known geological structure of the bedrock and in certain cases with the character of the soil cover, it is possible to draw certain conclusions concerning the suitability of the images for being the basis of an analysis of the tectonic and structure of an unknown area and of the capability of these properties in the bedrock to influence the actual morphology in creating morphological features related to the rock structure.

Method

For considerations of space no account in full of the method of analysis and the suitability of the different MSS-bands shall be given here. The procedure is in principle the same as in every analysis of maps and images. The lines that can be observed, are drawn on a transparent overlay and thereby also less conspicuous lines are often inserted in a linear pattern that has already been marked with the aid of distinctive axes or lineaments in the image. Thus, the lines often prove to be integrated into systems or patterns more or less pervading and characteristic of the whole area.

Which landscape elements are visible?

When analysing the images in question certain of the elements in the physical landscape appear very distinctly. That is the case especially with the border-

<u>line between land and sea</u>. It is drawn extremely clear cut and distinct, especially in images from band 7 (0.8–1.1 um). More short-wave signals, however, penetrate through the water and provide a picture of the bottom further and further out the shorter the wavelength is.

Another element in the physical landscape which appears very distinctly in the satellite picture, is the vegetation and particularly the woodland areas. In this case band 5 reproduces most clearly the occurrence of this component. The difficulties of separating the forest from water surfaces can easily be eliminated by comparing with images from bands that do not record any forests at all. Also band 4 can be used successfully because this band distinguishes fairly distinctly between forests and water surfaces.

The drainage network is a third element that comes through quite clearly, as do water surfaces of lakes and ponds. In the areas analysed the streams are insignificant and one must use band 5 or 4 in order to make them appear more distinctly. The relief or the land surface is the element in the physical landscape that is reproduced most vaguely in the satellite pictures. The third dimension does not appear directly in any of the bands,since only the entire overlapping coverage of two consecutive photographs can reproduce the real stereoscopic view of the terrain,and such an overlapping does not occur in the satellite pictures. The only case of distinct relief features in the pictures is when very high escarpments throw their shadows. This presupposes a favourable angle of the sun's rays.

As regards the images of western Scania only a few places have so marked escarpments that the shadow effect can be used to state the relief. However, this applies to the northern fault-scarp of Hallandsås and to some narrow and comparatively deep valleys, e.g the Sinarp Valley on Hallandsås, and to a number of valleys further to the east on the same ridge and to the pronounced ravine formations on the north-eastern slope of Söderåsen

What information can the images give?

Owing to the large distance between satellite and earth there comes into existence an effect of generalization that makes it possible to get a unique perspective on the earth's surface that no other pictures can provide. The objectivity of the images is complete because of the photographic reproduction. The subjective selection in the common map presentation and its disproportion as regards lines and symbols are entirely eliminated.

Through the multispectral recording within both the visible and invisible electro magnetic spectrum the different elements of the landscape can be reproduced separately in the different bands. But it is also possible to combine the different images and in this way secure particularly favourable reproductions of separate elements. In this manner the synthesis of the landscape, made up of the most perfect reproductions of each element from a certain wave range, can be much clearer than from the conventional picture. Especially three complex features in the physical landscape shall be dealt with in brief:

1. The coast-line orientation or the geometric contour of the land surface.
2. Lineaments in the terrain, i.e. morphological axes or lines and their possible joining-up into patterns. In the first place, the influence of the structural and tectonic factor is studied.
3. Single major landforms, their distribution and delimination.

Geometry of the land contour

The distinctness in the presentation of the land contour in the pictures originates in the fact that it constitutes the borderline between two basicly different elements. This makes possible a far-reaching and reliable analysis of the orientation and nature of each part of a coast line. The special advantages that the satellite picture includes, provide a general view that small scale maps cannot offer without missing interesting details of the coast line by the generalization and coarseness of the lines.

The satellite picture thus contains both the large-scale orientation that gives the general view, and the exactitude in the reproduction of details that admits of a thorough local analysis. This can be easily ascertained by using simultaneously one copy of the negative on a small scale and one on a large scale.

The fact that the image is void of the disturbances that may be caused by international or other administrative boundaries, enhances the character of general view in the image. These lines often interrupt an ordinary map analysis, e.g. an analysis of a coast line that belongs to different states, and thereby the total view is lost.

The multispectral recording offers a chance to identify in the image contour lines other than the actual coast line,which appears most distinctly in the infrared wave range. It may, for different purposes, be of great importance to be able to state where the coast line would run if the water level was lowered by different amounts. The most immediate practical application of this is that one can find out where the depth is especially small outside the actual coast line. To a certain extent the satellite picture serves as a sounding map. Another example of how these extended land contours can be utilized is as a argument for the continental drift theory that the continents fit into each other like the pieces of a puzzle. Wegener's efforts to prove the similarity of the land contours have been successfully continued by the Australian Warren Carey who used a terrestrial globe of 76 cm diameter, and the Englishman Sir Edward Bullard, who used data processing and found a very good correspondence between the land contours,if the 2000 m isobath is substituted for the coast line.

Even if the geometric forms of the land contours on both sides of the Öresund have nothing to do with drift movements, they are nevertheless of great interest.From the scientific point of view the task is to explain why the geometric configuration has got its present appearance. Several separate factors combine to give the coast line a certain orientation. Partly, the coast line is to a certain extent the reflextion of the morphology of the land surface, so that an indentation of the coast line originates where the land is low, and a projection in the form of a peninsula, headland or isthmus where the land is elevated. Another factor that is of great importance concerning Scania and Sealand, is the glacial action in the Quaternary. Ice lobes and moraine bows, radial eskers and melt-water channels are, no doubt, of importance to the orientation of the coast line in this area as are coastal currents and wave abrasion, which chiefly co-operate toward the straightening out of the coast line.

Besides the factors mentioned the position and other properties of the solid bedrock have a fundamental function with regard to the extension of a land area and it can also be traced in the details of the geometry of the land contours. In order to find out the dominating directions it is necessary to use parallel lines on transparent cover, placed over the satellite picture.

In this special partial investigation the purpose has been: A. to find common features in the direction and configuration of the land contour on both sides of the Öresund.

B. to examine if the properties of the bedrock such as stratigraphy, tectonic and structure show any correlation with the main features of the geometry of the land contour.

It is evident from fig. 2 that shows the composition of the bedrock in its main features, that the two land areas on both sides of the Öresund make up one geologic unit, seperated only by a secondarily developed and water-filled depression. Furthermore a syncline-like formation can be seen in south-western Sealand, consisting of younger, sedimentary rocks, which have been preserved there in thick layers but have been thinned out toward north and south. The axis direction in this large "fold" is NW to SE and Sealand has its largest breadth in this very direction. The same direction is also conspicuous in certain other features in the land contour, as indicated by Line B in fig. 3.

Two other directions, Line A in ENE-WSW, and Line C in N-S, can be discerned in the large-scale course of land contour around the Öresund, even if a certain straightening out has taken place secondarily. A more detailed account of the motivation and orientation of the established lines would carry us too far. They have only been indicated here to show the possibility of getting from satellite pictures "major lines" in the course of a complicated coast line. No tectonic and structural features in the bedrock having been pointed out in detail, there certainly exist such properties and they constitute the background of the main features in the geometry of the land contour.

Morphological lineaments in the Precambrian rock area

Morphological trends in the Scanian Precambrian area that are visible in the satellite picture, are made up of two systems of linear elements, the one in

NW-SE and the other in N-S. Both of them are already well-known, but they appear so distinctly on the image that they might have been established without diffuculty even in an unknown area.

An interesting feature in the two systems is that they seem to undergo a radical change in direction, although in different ways. The NW-SE system assumes furthest in the NW a more E-W orientation, clearly documented in the delimiting lines of the two Precambrian horsts of Kullaberg and Hallandsås. The north-southerly direction, however, turns in the south to NE-SW. Accordingly, it does not here form a straight line but is bow-shaped with the concave side toward west.

The different courses of these two lines are probably connected with their different origins. The NW-SW lineament has a purely tectonic character and is genetically associated with the release of stress in the bedrock (tension type) that appears in connection with the downwarping of south-western Scania. The same conditions gave rise to the formation of the dolerite dykes and horsts in the middle diagonal part of Scania. The N-S lineaments are associated with the fabric element in the form of the schistosity in the gneiss which on the whole strikes north-south and dips toward west. That s-planes in a metamorphic rock change their orientation over a long distance is a frequent phenomenon. That is probably the case here, too, and makes up the general background of the indicated bow-bend of the morphological trends in the south. But this more NE-SW direction in the south has also a purely geometric factor. Since the highland of south Småland decreases in height toward south, the westdipping s-planes for mere geometric reasons give rise to an outcropping in the terrain that corresponds to the bow-shaped line with concavity toward west shown in the pictures. The topography of the area is, in great features as in small details, characterized by the above-mentioned occurrence of two crossing linear clements in the bedrock. Thus there are lakes elongated in two directions perpendicular to each other. This applies e.g. to Lake Syrkhultasjön NW of Sösdala in central Scania. The angle-like form of this small lake, as of many others, reflects the influence in morphology of the two directed clements that occur in this bedrock, namely one surface element in the direction N-S, and one linear element in the direction NW-SE, which are constituted, on one hand, by the schistosity of the gneiss with s-surfaces and, on the other hand, by the prevailing tectonic joint directions that create the large faults and joint lines.

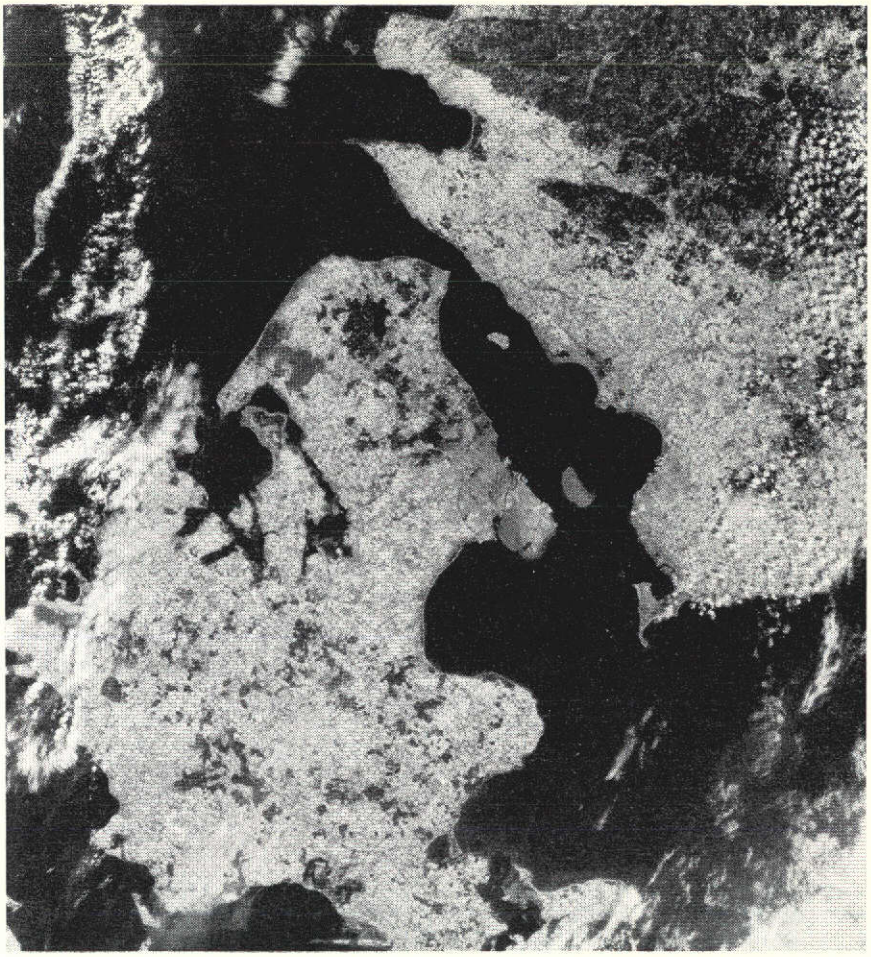

Fig. 1. ERTS-1 image of the Öresund area, Sept. 2, 1972
(1041-09471-5).

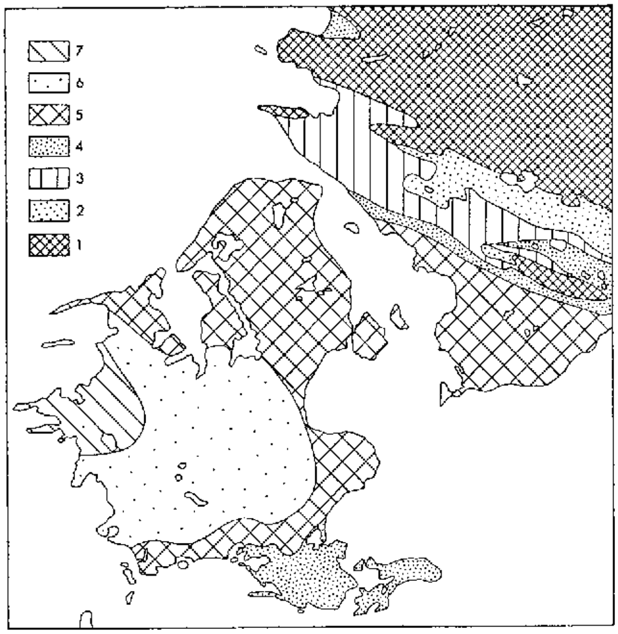

Fig. 2. Main bedrock regions in the area around the Öresund.
1. Archean, 2. Cambro-Silurian, 3. Triassic-Jurassic, 4. Senonian, 5. Danian, 6. Paleocene, 7. Eocene.

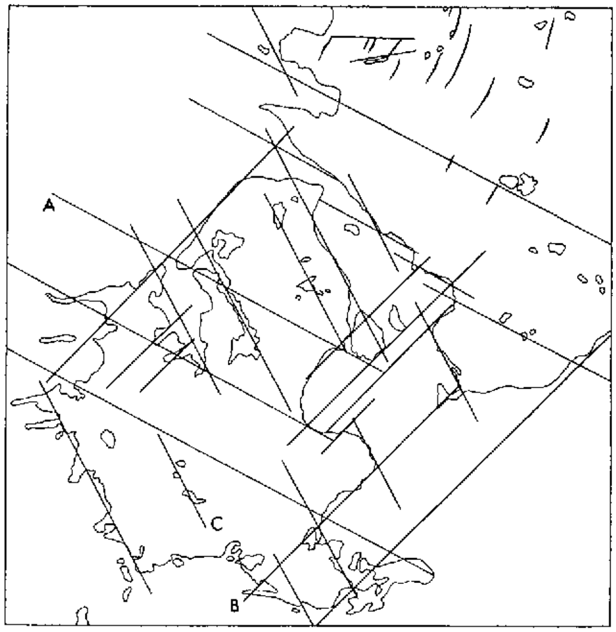

Fig. 3. Morphological lineaments.
A. Linear element in NW-SE
B. " " " ENE-WSW
C. " " " N-S

SOME MORPHOLOGICAL FEATURES IN THE REGION OF THE GREAT SWEDISH LAKES

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Abstract: An ERTS-1 image of March 19, 1973, of the Middle-Swedish Lowlands around the Great Swedish Lakes was analysed for the basic geomorphological patterns. The usability of the various MSS-bands in geomorphological analysis is discussed. Attention is paid to some structures, the role of which seems to be more important than supposed earlier.

INTRODUCTION

The starting-point of this morphological study is an ERTS-1 image of March 19, 1973 (fig. 2) covering part of the Middle-Swedish Lowlands (the region around the Great Swedish Lakes Vänern and Vättern). The images is nearly cloudless. Tne pictures used for analysis are enlargements of the 70 mm negative. Their approximate scale is 1:386 000 and their margin has the direction of about N19°E.

The available images originate from ERTS-1's multispectral scanner (MSS) in four spectral bands: two from the visible field: 0.5-0.6 um (band 4) and 0.6-0.7 um (band 5) and two from the near infrared field: 0.7-0.8 um (band 6) and 0.8-1.1 um (band 7). Recently the image has been published also by SVENSSON (1973) as a colour composite (processed according to colour enhanchement technique by B. Henriksson, Lund) in three colours (bands 4,5,7). Only the images of band 5 (red) and band 7 (blue) are used in fig. 2 in this paper (scale appr. 1:1 400 000).

The following report focuses, in the first place, on the question, how morphological objects on a peneplained and slightly undulating surface of Archaean rocks with soils of till and sedimentary clays and sand and almost entirely covered by vegetation (except for water surfaces) some out on an ERTS-image.

GENERAL VIEWS

Band 7 gives contrasty pictures of the hydrology, band 5 of the vegetation. Band 4 and 6 can, in this respect, provide only a little more information. Thus, the satellite picture gives only to a relatively small extent direct information of the landforms and soils in a gently undulating area covered with vegetation. There are, however, extremely small areas where the material lies uncovered and its reflection and absorption properties can form the basis of observations about soils and landforms. The most important data are obtained indirectly via the vegetational patterns and the orientation of the watersurfaces.

Nor is it to be expected that the satellite picture of densely populated, well-mapped and relatively well-known areas should to a greater extent give quite new information about the landforms. Therefore the discussion chiefly concentrates on two questions: 1. Can the pictures give us supplementary information in certain respects? 2. To what extent is it possible to trace already known features with the aid if the data provided by the satellite pictures?

The combination of the images of hydrology and vegetation gives the information that the satellite picture can provide about the forms of the even Archean bedrock surface. The shadows, however, indicate directly the terrain forms.

SHADOWS

The image is taken at 9.47 MGT or 10.47 Middle Swedish Time. The sun is in the SSE with an altitude of about 28° above the horizon (Data users handbook). This fact entails shadow effects emanating from high and steep slopes on the N and NW faces. These are most distinct in band 7 (and 6). Therefore this picture shows e.g. the mountains of Västergötland in three-dimensioned relief (the terraces of Kinnekulle and the summit drumlins, however, are most visible in band 5 through the vegetation picture). Likewise shadows are marked off in the fissure valley landscape in the NE coming from the fault-scarps that make up the boundaries of the Närke Plain in the S. Also the Tisaren-Sottern and Avern lines give rise to shadows.

HYDROLOGY

The hydrology appears incomparatively best and with great distinctness in the bands 6 and 7 (blue colour fig. 2). The water surfaces absorb almost all the radiation in the near infrared area, while the adjoining objects have high reflection values (KONDRATYEV et al. 1973). The image corresponds closely with the general topographic map and the lineaments of the lake surfaces are easy to survey. Not only the large streams of the flowing water bodies are visible, e.g. Göta älv River, Klarälven River, Letälven-Gullspångsälven River, Motala River, but also much smaller streams whose breadth can be calculated at 30-40m, can be discerned for tens of kilometres, e.g. Lidan River, Tidan River, Svartå River in Östergötland and so on. Perhaps the absorption of moist meadows on the floodplains make the lines broader and darker. Small lake surfaces with a diameter of ca 200 m can be perceived against the vegetation picture in band 7. Shallow lake floors and, possibly, vegetation-filled parts of the lakes can be observed (Lake Dettern, Hindens Point in Vänern, Lake Tåkern and so on).

VEGETATION AND SOIL

The most important morphological indicators are provided indirectly by the vegetation image, chiefly in band 5. Here the loose deposits are of great importance for the distribution picture. The late-glacial sea and lake floors have been wave-washed during the land upheaval and small relative differences in altitude of 5-20 m are clearly manifested in cultivation and vegetation picture. With the aid of the vegetation an almost correct picture of the fine sediments of the cultivated plains and valleys, especially marine clays, contra the wave-washed moraines with coniferous forest can be obtained. This applies to areas below tha marine limit. Above the marine limit, however, this way of looking at things becomes unreliable. Cultivated drumlin ridges on the plateaus are light with higher reflection, while valleys and extensive, lower surfaces, covered with mires and coarser sediments, are dark.

As a special, dominating trace on the image may be noted the Middle-Swedish terminal moraine line (the continuation of Salpausselkä) from the Karlsborg area on the western shore of Lake Vättern over Mount Billingen (fig. 1) towards Hindens Point in Lake Vänern. The distal sand sediments ENE of the northern part of Billingen form broad forest belt right across the Tidan Basin. South of this zone lie rows of narrow, wooded terminal moraines; in the north drumlin, structures are very conspicuous.

Two bow-like forms to the SE and E of the southern shore of Lake Skagern are mysterious. They have no equivalents on the topographic and geological maps, but they have been interpreted as composed of soils.

STRUCTRUAL LINEAMENTS AND LANDFORMS

In the South-Swedish Highland E of the southern end of Lake Vättern the geological map with its Småland and Värmland granites of Gothic age lays special weight on the strains of Smålandic porphyries in bodies with the main direction about E-W. Band 7 as well as the topographic maps provides data about valley lakes of the direction N 10° W. In other respects, the plateau lakes and the other structures on the plateaus give no clear direction patterns. But band 5 gives for the whole area the marked impression of the above-mentioned direction pattern, here parallel to the schistosity zone between the granite and the pre-Gothic gneisses that runs near the western side of Lake Vättern. This striping continues in over the Almesåkra plateau, where, accordingly, the valley pattern is not radiating. The direction pattern stands out as a main characteristic, far more clear-cut than on the topographic maps. The pattern may have been exaggerated by drumlin structures, but it is most salient in the bedrock. The region ends to the north in a fissure valley parallel to the southern shore of Lake Tåkern and the Cambro-Silurian boundary of the Östergötland Plain. The valley runs about 8 km south of this Cambro-Silurian boundary.

About 10 km to the west of the southern end of Lake Vättern the borderline of the West-Swedish gneisses is crossed. The valley pattern is entirely changed. The finely streaked lineament in the east turns to more irregular valley patterns, which surround wooded plateaus and are smoothed out towards the plains in the north. The pattern is suddenly interrupted at the southern fault line of the triangular Billingen-Falbygden region where Cambro-Silurian rocks take over.

The plains to the west of Lake Vättern are dominated by a lineament of about N 20°E direction, the most important elements of which are fault lines bent like a bow towards east. The fronts towards east often rise only 5-20 m above the clay-covered plains on the low plateau sin the east, but these low values are sufficient for generating distinct patterns. The line of Värmlandsnäs-Kållandsö-Anten through Lake Vänern (where the differences in altitude are greater than at the fault front) and further to the south is the strongest one. The strike direction of the gneiss varies but the direction within the sector N–S is prevailing. The most deviating line of the picture is the west–easterly line from the northern end of Lake Anten in the SW corner ("Hackebergsskogen").

The structures of the fissure valley landscape in the north–east of the image with its fault lines, especially in W–E give a typical picture of a block landscape. It is designed by the vegetation (band 5) together with the shadow effects mentioned, and the image provides a three–dimensioned impression. Some features, that are not observable on the topographic map, may be pointed to. The fine striping in $N10^{\circ}W$ in the landscape SSE of Lake Tisaren is salient in the ERTS–image, as is the locally pronounced linear structure E of the Tjällmo Plain (near the east map edge), which corresponds with the orientation of some fairly deep fissure valleys in the area (Lakes Lien and Stor–Tron).

CONCLUSIONS

A combination of band 5 and 7 gives the best result when analysing the landforms on a smoothed down Archean bedrock. Good three–dimensioned effects can be obtained from heavily undulating surfaces when the sun is low. The combined observations add useful information to the traditional morphological description. The details of the image can group themselves together into macropatterns that have not before been stressed in the morphological description, partly because they have not been observed since the maps have not given enough information and the pattern, moreover, has not appeared clear–cut on large–scale aerial photos, partly because the observed features have been considered to be of less importance. But these features, seen clearly and globally integrated by the ERTS–image, give a hint that more attention should be paid to such landform features. The satellite picture may function as an incitement for new ideas.

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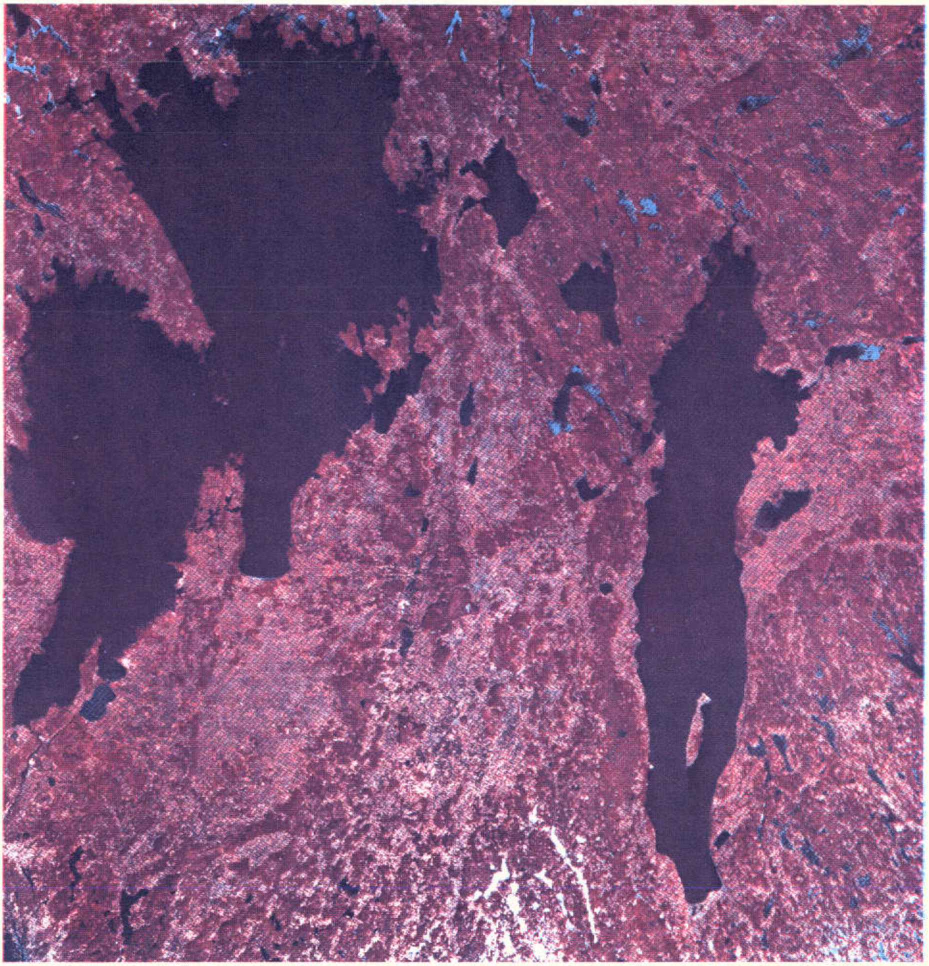

Fig. 1. The regions of the lakes Vänern and Vättern, March 19, 1973 (1239-09472). Approx. scale 1:400 000. The picture is composed of the MSS bands 5 (red) and 7 (blue).

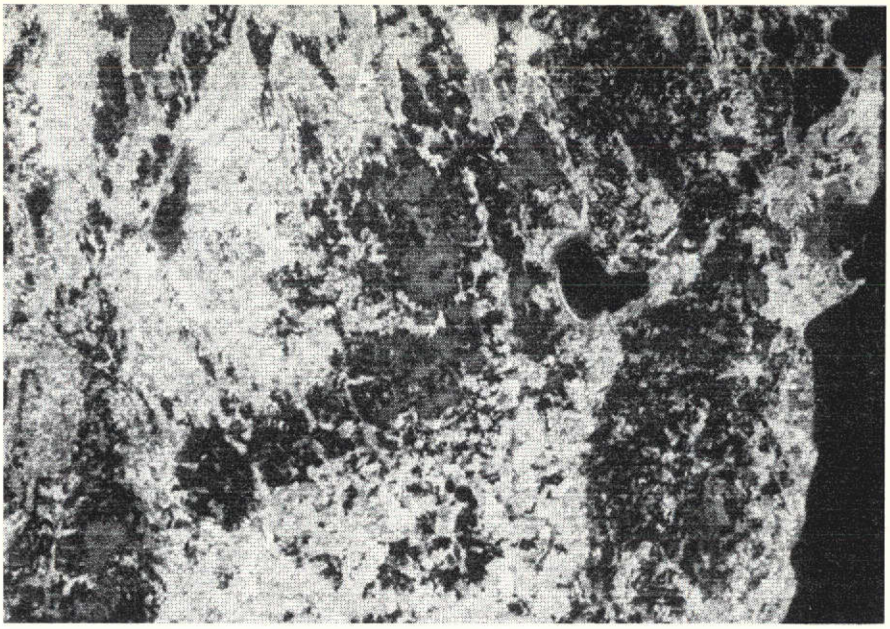

Fig. 2. A detail of Fig.1. The Middle Swedish terminal moraines from Mount Billingen in the W to the shore of Lake Vättern (MSS, band 5).

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY

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ID

DATE January 25th, 1974

PRINCIPAL INVESTIGATOR Harald Svensson

GSFC FO 426

ORGANIZATION Department of Physical Geography

University of Lund, Sweden

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
1239-09472-5-7				Bedrock Drumlin End moraine Fault Hydrology Lake Lineament Moraine Peneplain

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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TECTONIC ANALYSIS OF SOUTH-WESTERN SWEDEN BY MEANS OF ERTS IMAGES

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Abstract. ERTS images of part of south-western Sweden have been studied. Tectonic lineaments and other structures in the bedrock have been observed and compared with the map of the pre-Quaternary rocks of Sweden. Some previously unknown lines are discribed and discussed.

INTRODUCTION

The Precambrian rocks of south-western Sweden are comparatively poorly known. Modern geological large-scale maps exist only for a few small areas. The present view of the main features of the Precambrian rocks is evident from fig. 1. Line 1 is a tectonic line. It coincides in the south with the boundary between Gothian and pre-Svecofennian rocks. Along this line movements have occurred since the Late Gothian (Lundegårdh 1970, p. 120). Line 2 is a continuation of the Vermlandian mylonite zone which is reported to be of either Late Gothian age (Magnusson 1962, p. 77, Lundegårdh 1970, p. 120) or of Dalslandian age (1150 - 900 m.y.) (Magnusson 1970, p. 7). The Cambro-Silurian of the Billingen-Falbygden area is bounded in the west by a fault (line 3). The fault is supposed to have had its origin in the same time interval as the intrusion of the dolerite (Regnéll in Magnusson et al. 1963, p. 256). The dolerite is now dated to the Carboniferous-Permian boundary (Mulder 1971, p. 18 and Priem et al. 1968 according to Welin 1971, p. 266), and therefore it is possible that movements occurred along the fault line in this period. The faults of the Vettern area (4) are believed to be of old origin but particularly active in the Permian (Magnusson in Magnusson et al. 1963, p. 371).

IMAGERY AND METHODS

ERTS images have been studied from two recording dates, viz. September 2, 1972 and March 19, 1973. The area covered by the images is seen in fig. 1. The images were interpreted chiefly by the use of diapositives on 1:1 000 000 and also paper copies of the four MSS-channels, channel 4 (0.5–0.6μm), channel 5 (0.6–0.7μm), channel 6 (0.7–0.8μm) and channel 7 (0.8–1.1μm). In the geomorphological analysis a combination of the images from channels 5 (fig. 2) and 7 (fig. 3) turned out to be most appropriate. Tectonic lineaments and other structural features in the bedrock are reflected in channel 7 particularly in the contours of the lakes but also in the light-coloured cultivated areas. Channel 5 very strongly emphasizes the cultivated districts, which are commonly seen as light bands in the image. The March images have chiefly been used for analyzing the north-western part, which is covered by clouds in the September images. In other respects the September images offer better contrasts.

Diapositives of the images have been studied by means of an Interpretoskop (Zeiss, Jena). In doing so, it is possible to get simultaneously a picture of channel 5 and 7 respectively in either eye. In the analysis the images were covered by a transparent film, on which the observations were marked off. Subsequently the lines were topographically identified by means of large-scale maps. In particular the map of the pre-Quaternary rocks of southern Sweden (Magnusson 1958) was utilized in the interpretation. Thereby it was evident that the images have so an exact scale that when this geological map is placed on a light-table and a light diapositive of an ERTS image is put on top, the pictures coincide almost completely. Thanks to this similarity the structures on the map and in the image can be compared directly.

TECTONIC LINES

A clear striation starting from the southern end of Lake Vettern and extending southwards is visible in the images. The striated area is bounded in the west by a comparatively sharp line (A) extending from the south-western corner of Lake Vettern. What gives the striation in the images of channel 7 is a combination of elongated lakes and cultivated valleys. In channel 5 the striation is caused mainly by the cultivated valleys alone. The lines are not absolutely continuous but congregate into a uniform pattern (fig.4).

Further westwards a light-coloured line (B) with an approximate northerly direction in the south and a north-north-easterly direction further northwards can be discerned. On the whole no lakes are found along this line except in the northernmost part. The continuation of the line is very distinct in the ERTS images lying north of the ones treated here. In those images it can be followed along the entire line that is marked as no. 3 in fig. 1. Additional lines approximately parallell to line B can be seen in the images treated herein.

In the southern part of line B there is a major interruption where the picture is dominated by a semicircular pattern (E) formed by lakes and certain valleys.

A line (C) with the direction N 40° - 48° W was observed in the southern part of the area studied. In the extreme north-west it follows the coast-line, while further to the south-east it forms the boundary between the coastal lowland and the highland. The line becomes indistinct in the vicinity of the Lagan River but regains its distinctness in the extreme south-east.

In addition to the above mentioned curved pattern (E), curved lines were observed east and north-east of Onsala and between Borås and Lake Åsunden (F).

In the north-west a network of joints appears. It is possible to state that there exists one east-north-easterly to easterly joint system in the north and one north-easterly system to the east of line 2 (fig. 1) and further soutwards. The systems cross one another east of the Onsala Peninsula. Line D is a conspicuous line within this area. In the north it is made up of wide valleys oriented almost north-south, while in the south it is narrow and filled with lakes and extends N25^{o}W. Some additional north-south valleys are marked in the north on the map.

TENTATIVE INTERPRETATION

The A-line and the lines east of it. A comparison with the map of the pre-Quaternary rock of southern Sweden reveals that the lines partly coincides with the schistosity zone ("protoginzonen") within the Precambrian rocks. However, line A itself is partly to the west of the schistosity zone. In connection with practical-geological investigations in recent years it became apparent that a schistosity and fracture zone extends also along the valley of the Lagan River (Stanfors 1973, p. 24), which is largely coincident with line A. Also the striation indicated furthest to the east, on the map (fig. 4) is located outside the schistosity zone, but also here Stanfors (1973, p. 25) reports tectonized zones, which may be connected with the schistosity zone. Accordingly, the images would give certain guidance in the delimitation of this zone.

Line B and lines parallel to it. In its southern course, line B cuts across the strike of the gneiss. In the interruption of the line at the E lines there is an amphibolite, zone, which partly extends parallel to those lines. It is strange that line B, if interpolated through this interval, will pass through a narrow gap in the amphibolite mass. However, because the area has not been mapped since 1895 and on this occasion only on 1:200 000, it is uncertain if the map reflects the real conditions. North of the interruption the line follows the strike of the gneiss for a short distance. An additional interruption is found where a zone of grey iron gneiss is wedged into the red iron gneiss with an almost east-west strike (see fig. 1). At this point the images show a system of slightly curved lines (F), which are caused by the schistosity of the gneiss. The direct connection between line B and the Billingen-Falbygden fault (line 3, fig. 1) is obvious, but also the line directly east of line B has a continuation in the Cambro-Silurian area. Consequently, it is possible that movements have taken place here close to the Carboniferous-Permian boundary.

Line C. The middle part of this line has been observed earlier and is reported to have the same orientation as other zones of weakness in the bedrock on the map sheet Halmstad (Caldenius 1966, p. 6). The most south-eastern part of the line reaches the Scanian fault area and comes to an end at the northern edge of Hörlinge Ridge. Hörlinge Ridge has the direction N 20^{o}W and in this respect is different from the other Scanian ridges which take a more north-westerly direction. With regard to the direction, line C coincides roughly with the Scanian ridges except for Hallandsåsen with its more west-north-westerly orientation. It is possible that line C is connected with the Scanian tectonics. It may be observed that line C in its extension into the sea in the north-west marks the boundary between the first signs of an archipelago to the north and an area almost free of islands to the south.

The fissure valley landscape in the north-west. Major joints of three main directions, viz. north, north-east and east-north-east are present. The tectonics may be compared with Nelson's (1913) and Larsson's (1963) observations in the gneiss area. Line D is probably made up of fissure valleys in its northern part and valleys caused by schistosity in its southern part.

The curved structures. When compared with the map of the pre-Quaternary rocks the bow-shaped pattern consistantly proved to be caused by schistosity (cf Röshoff 1968). It is obvious that this pattern is confined to areas with grey iron gneiss in all cases except possibly for the E lines.

REGIONAL DIVISION

On the basis of the observations a division into regions can be made. The area in the west with Gothian rocks makes up one region. East of this a fissure valley landscape begins, which is also characterized by the schistosity of the gneiss. It extends to line B in the east and line C in the south. To the east of this area lies the highland, which is characterized primarily by the roughly north-south lines. Along the coast and bounded by the lines B and C there is a lowland area with monadnocks. Furthest to the south is a triangular lowland limited by line C and the northern fault of Hallandsåsen. The lowland is mainly a plain except for a hilly landscape south-west of the indistinct part of line C.

CONCLUSIONS

The ERTS images are comparatively detailed and one image covers a large area. The images yield a surveyable view of large structures in the bed-rock not obtainable in other media. Two previously unknown major tectonic lines (B and C) were detected in the images.

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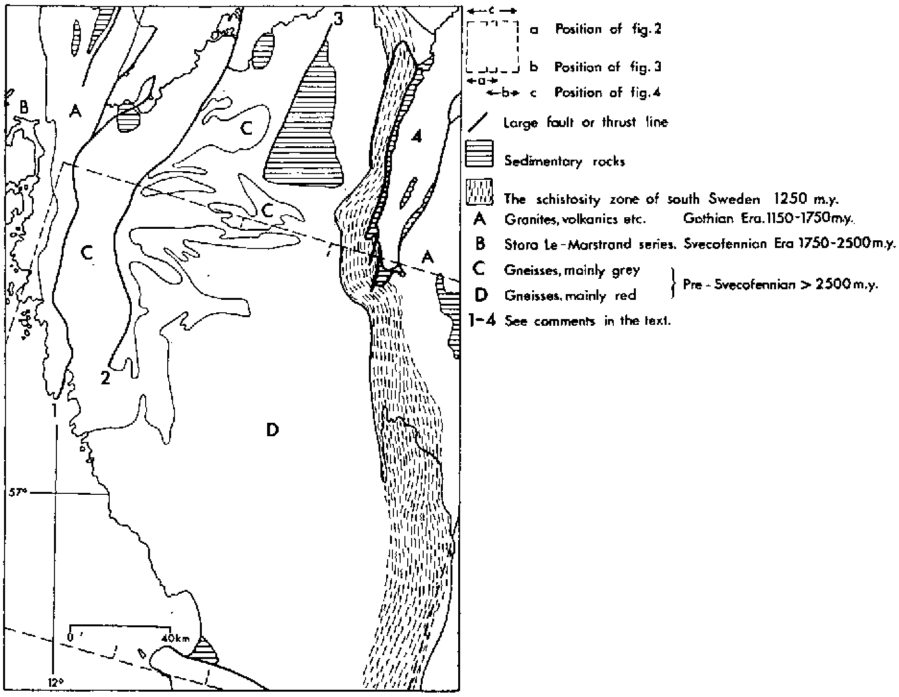

Fig. 1. Principal geological subdivision and tectonical structures of south-western Sweden according to Magnusson (1958 and 1979), Lundegårdh (1970 and 1971), Hjelmqvist (1973), De Geer (1910) and Rudberg (1970).

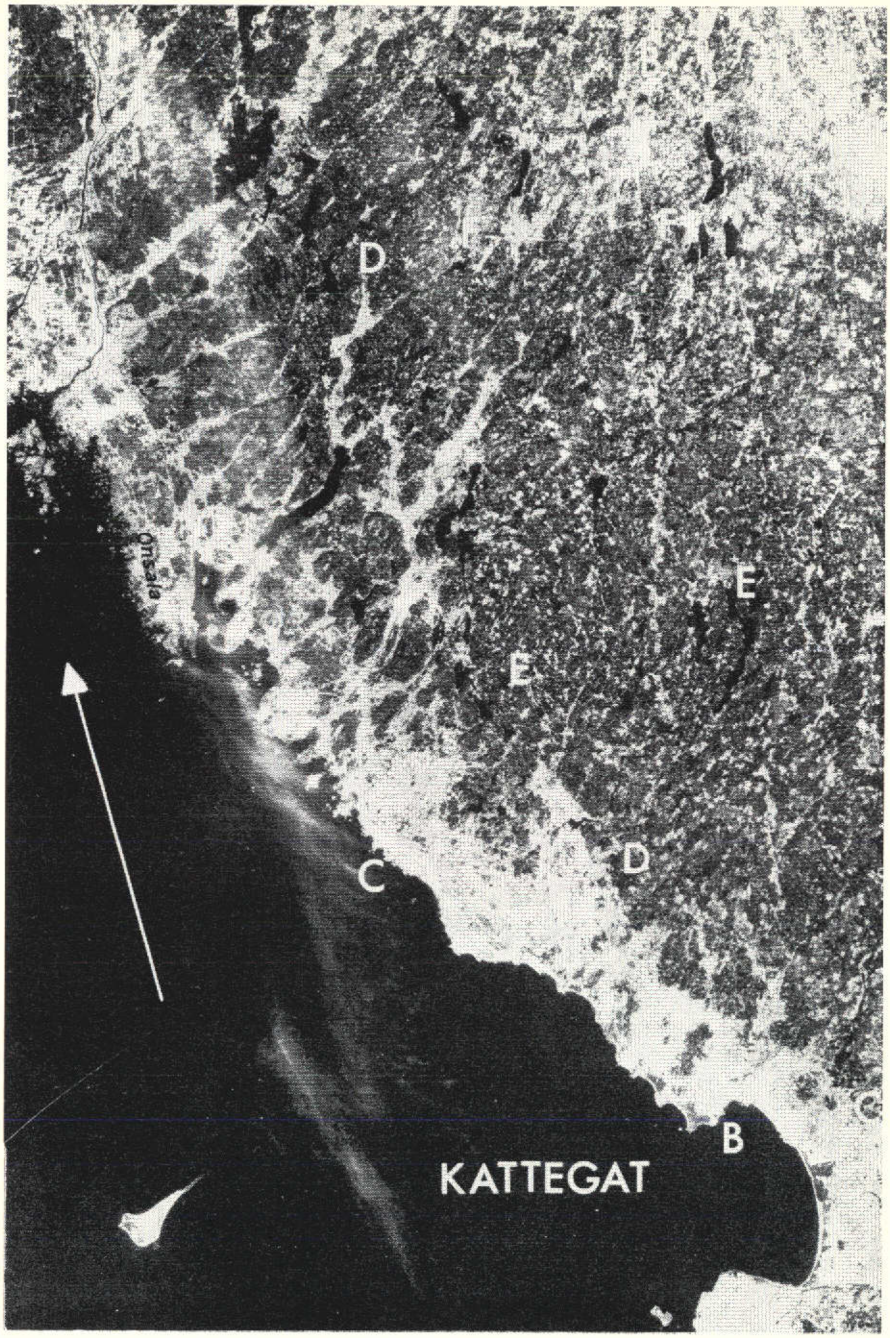

Fig. 2. Part of south-western Sweden in ERTS image of MSS-channel 5 (0.6-0.7 μm) from March 19, 1973. Approx. scale 1:1 000 000. Position of the image is indicated in fig. 1.

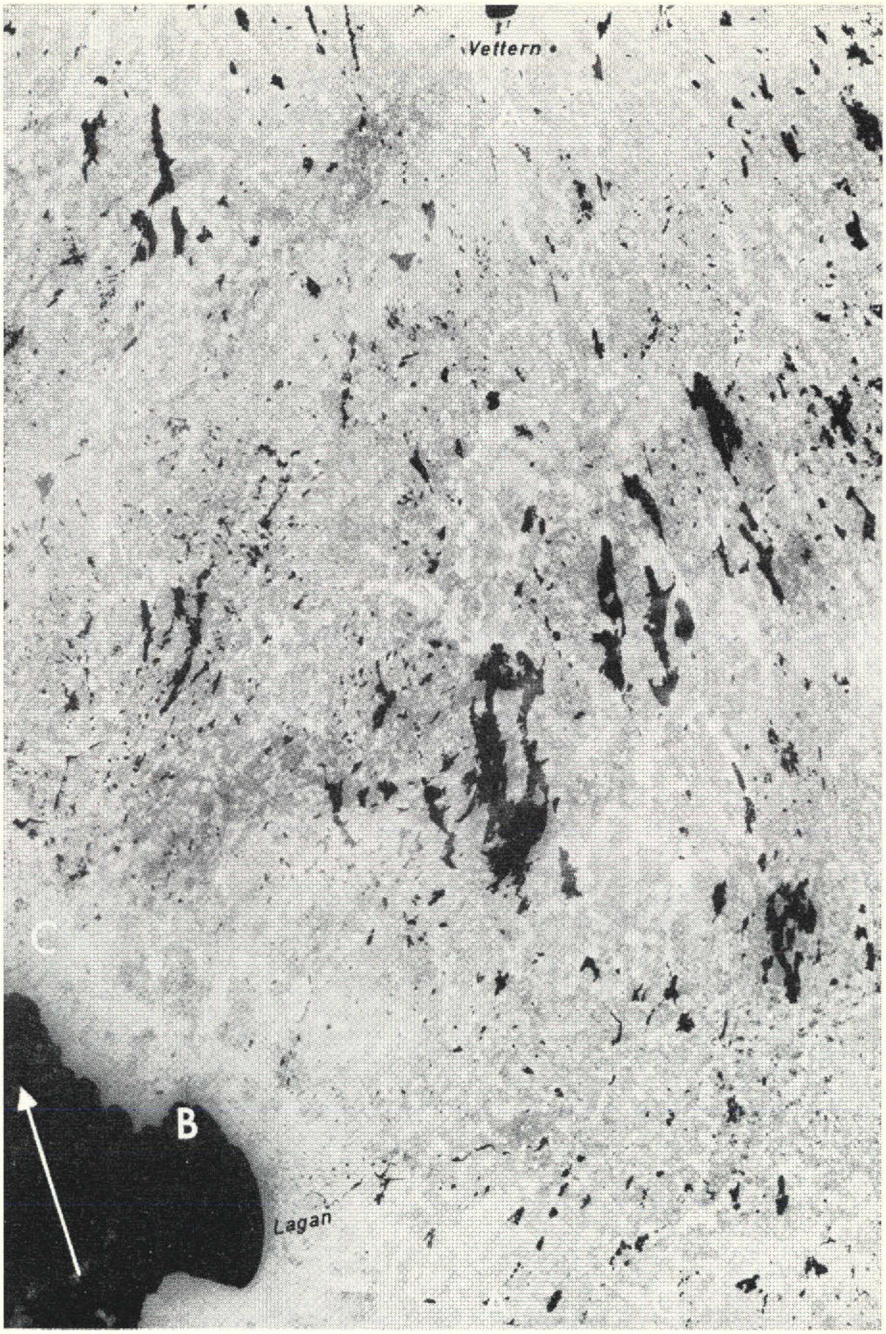

Fig. 3. Part of south-western Sweden in ERTS image of MSS-channel 7 (0.8–1.1 µm) from September 2, 1972. Approx. scale 1:1 000 000. Position of the image is indicated in fig. 1.

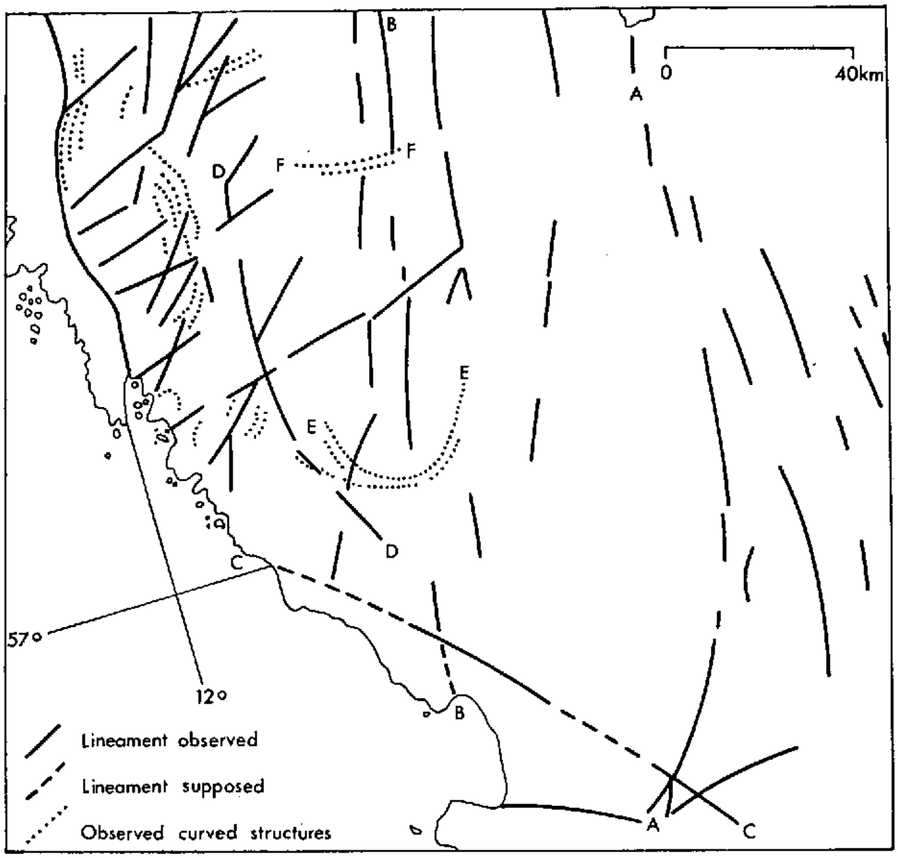

Fig. 4. Tectonic lineaments and curved structures in part of south-western Sweden according to the interpretation of ERTS images. Position of the map is indicated in fig. 1.

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RECORDING OF COAST LINE AND DEPTH CONDITIONS AT THE FALSTERBO PENINSULA, SOUTHERN SWEDEN, IN ERTS-1 IMAGES

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INTRODUCTION

As test area for study of coastal and submarine features in ERTS images the Falsterbo peninsula was selected (SVENSSON 1972). The very flat peninsula that is bounded by the Baltic in the south and the Öresund in the north, is built up by glacial and marine deposits. The surrounding sea is very shallow and the peninsula is intensely used as recreation area.

When the study started, only imagery from ERTS passages in the autumn of 1972 was available.

MATERIAL AND METHOD

The material used in this study is enlarged paper prints (appr. scale 1:100 000) from the ERTS-1 multispectral scanner. Over the prints transparent plastic film was placed. On the plastic film the land-water borderline was drawn. Then a comparison was made between the borderlines marked on the basis of the ERTS-1 images and conventional aerial photographs, the new topographic maps and the new economic maps of the area.

In order to find out how deep into the water the ERTS scanner could record, the paper prints were compared with nautical charts of the water areas around the Falsterbo peninsula. The nautical chart was reduced from 1:65 000 to 1:100 000 in order to make a comparison easier. For the same reason the new topographic maps were also reduced, in this case from 1:50 000 to 1:100 000.

The ERTS image analysed was recorded on October 7, 1972 (Fig. 1). The aerial photographs available for comparative studies are from 1966, 1967 and 1968. The nautical chart is originally from 1934 but was revised in 1972, though not with regard to the coast lines. The fact that the material used for the comparative studies is not of the same age as the ERTS image may be of some signification as the morphology of the beaches at the Falsterbo peninsula undergo changes relatively fast through shore-drifting, submarine, exploitation of sand for industrial use and wind erosion. The ever-changing configuration of the island of Måkläppen just outside the peninsula is a well-known phenomenon.

The fact that no stereoscopic vision could be obtained on the ERTS-images made the comparative studies more difficult. Colour enhancement technique was tried by means of a three colour combination projector that could be used for some days through the courtesy of the Research Institute of National Defence.

CONTOURING OF THE LAND-WATER BORDERLINE

MSS band 4 (0.5-0.6 um). Drawing borderlines between land and water is difficult (Fig. 2a). A minimal correspondence between the ERTS images and maps and conventional aerial photos is obtained. The northern entrance to the Falsterbo Canal appears in a very diffuse way. In this spectral band a large part of the shallow sand areas and bottom features are recorded compared to the other MSS bands (cf WILLIAMS 1973).

MSS band 5 (0.6–0.7 um). Band 5 reaches the limit of the visible spectrum. Making borderlines between land and water is very difficult and uncertain, because the shallow near-shore sand areas could be confused with beaches (Fig. 2b). The northern entrance to the Falsterbo Canal is possible to discern, though very obscurely. Parts of the pier can be seen on the south side of the canal. Beaches can very well be seen in this MSS-band.

Images from band 5 could be used for inventories of beaches, investigation of submarine sand deposits, which can be exploited for industrial use, and for the detecting of beach areas that have been damaged by oil catastrophies.

In band 5 the island of Måkläppen seems to be a part of the mainland, but that is not the case in reality. Parts of the Flommen shallow water areas inside the western coastline have been recorded. The reason for this may be that the Flommen water areas have no light sandy bottom but a muddy dark one and thus can easily be separated from the brighter land- and sand-areas.

MSS band 6 (0.7–0.8 um). This band corresponds to the interval just outside the visible spectrum on the verge of the near infrared spectrum. Drawing the land-water borderlines is also here difficult (Fig. 2c). The correspondence between maps, and conventional aerial photographs is still not very good. Some of the shallow bottom areas give the impression of being landstretches. The Falsterbo Canal is distinctly registered in this band.

MSS band 7 (0.8–1.1 um). The images recorded in MSS band 7 provide in this comparison the best material for contouring the borderline between land and water (Fig. 2d). It coincides very closely with the borderlines on the maps and aerial photos. That can, by among other things, be explained by the fact that the near infrared does not penetrate water.

The Falsterbo Canal is easily seen. The recording of the canal can give an idea of the resolution of the imagery. In reality the width of the canal is about 90 m. The canal is linear but, the MSS registration in band 7 indicates an irregular contour. The canal is recorded wider in this spectral band compared to band 6. A possible explanation to this may be that band 7 to a higher degree has registered wet areas adjacent to the canal than has band 6.

The Flommen water areas on the western part of the peninsula are well indicated, i.e. the water areas that are wider than 90-100 m.

Colour enhancement. The colour composite made from the MSS bands 4 (green), 5 (red) and 6 (blue) were very useable for analyses. The coast line is easily fixed. The land areas are shown in a yellowish red colour. The determination of the land-water borderlines made by colour combination is very well in accordance with the one made with the help of MSS band 7 in black and white paper prints. Other combinations of the MSS bands did not prove to be so good in this context.

DEPTH PENETRATION

As alredy mentioned, a nautical chart on the scale of 1:65 000 was used in order to find out to which depth bottom features around the Falsterbo peninsula could be recorded. The depths on the nautical chart were measured at mean sea level in 1934. It is a well-known fact that considerable shoredrift takes place in the area and that the bottom morphology and the depths probably have changed. By comparing the nautical chart with the new economic map of 1969, we find, that the small island of Måkläppen has grown quite a lot. This also happened to the small spit on the southern side of the peninsula.

The nautical chart's depth contours and depth figures were compared with the light areas of the enlarged ERTS pictures that had been found to constitute submarine sand areas. Also in this case the same colour-enhanced ERTS images were used. Due to absorption of the near infrared by water the only images that could be used for this investigation, were registered in the MSS-bands 4 and 5.

MSS band 4 (0.5-0.6 um). The registration in this band is diffuse partly because of haze, but an indication is given that it is possible to see the bottom down to 3 m depth.

MSS band 5 (0.6-0.7 um). This band produces a more distinct registration. The contrasts are sharper. In the upper part of the photograph (north) there are clouds making an exact drawing of the borderline impossible there. A registration down to a depth of 3 m is found. It is hard to state the depth exactly, because the bottom is evidently sloping strongly (the 1 m-figures are written just beside the 3 m contour in several places). Studying the bottom features around the island of Måkläppen underlines the fact that a recording down to a depth of 1 m is possible everywhere in this area. It must be pointed out that these observations are made only on near-shore sand bottoms.

A comparison with conventional aerial photos was also made. The shallow sand bottoms are recorded very clearly on these aerial photos. A more complete registration of depth conditions can be found on the aerial photos, but not deeper than down to the 3 m contour line in this area. A very sharp borderline appears approximately where the 3 m contour runs.

Colour enhancement. The colour composite made from the MSS bands 4 (green), 5 (red) and 7 (blue) gave a good survey a depth conditions. Shallow bottom areas are shown in green and blue colours. The colour photo shows that the outer margin for recording the bottom well follows the 3 m contour of the nautical chart.

The colour composite made from the MSS bands 5, 6 and 7 does not record shallow bottoms as well as the previous combination.

CONCLUSIONS

The following conclusions can be made with the reservations for shortcomings in the material available for the comparative studies. When outlining the land-water boundary the most distinct contour is obtained using MSS band 7. The colour composite giving the best result and well in accordance with one of band 7 was the combination of MSS band 4, 5 and 7.

MSS band 5 gave the most adequate imagery for surveying depth conditions in shallow water areas. For a near-shore pure-sand bottom the multispectral scanner can register to a depth of 1 m. There are some indications that a registration down to 3 m would be possible.

The recording of depth conditions is strongly influenced by the turbidity of the water and the different types of bottom.

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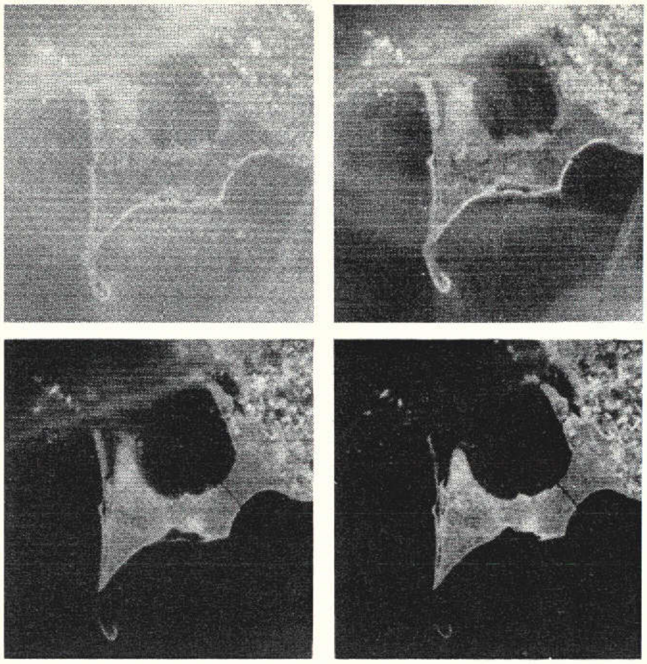

Fig. 1. Multispectral images of the Falsterbo peninsula of Oct. 7, 1972 (1076-09413); band 4 (0.5-0.6 µm) top left, band 5 (0.6-0.7 µm) top right, band 6 (0.7-0.8 µm) bottom left and band 7 (0.8-1.1 µm) bottom right. Approx. scale 1:400 000.

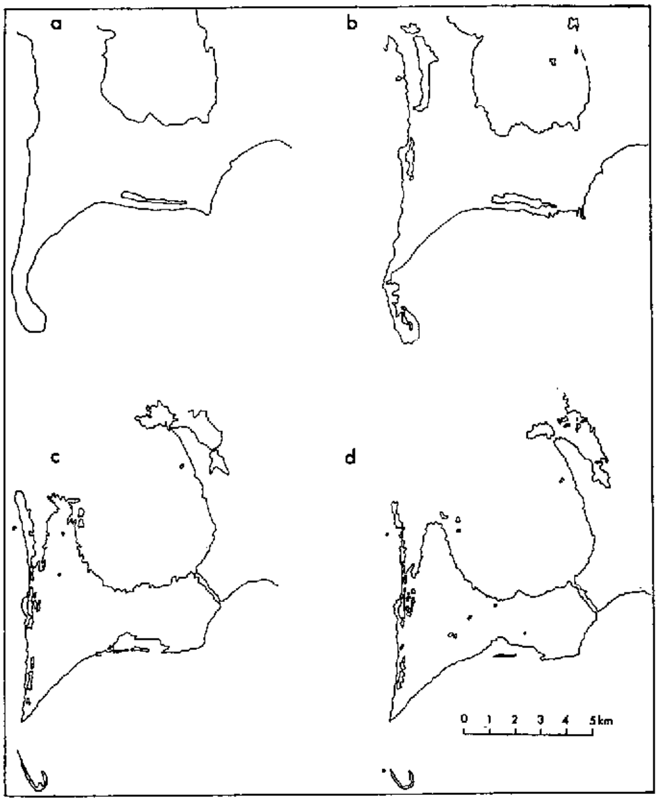

Fig. 2. Land-water borderline drawn from the same multispectral images as in Fig. 1.

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-6-7				Canal
-7				Coast line
				Island
				Peninsula

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CLOUD STUDIES BASED ON ERTS-1 PICTURES

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Abstract. The paper shows by some examples the applicability of the ERTS pictures in studies of certain mesoscale cloud patterns and structures that have up till now been rather difficult to analyse. The firstclass resolution ability of the pictures makes then most suitable for such studies. Their analytical value increases also because they are produced within four different wavelength bands, 0.5-0.6 µm, 0.6-0.7 µm, 0.7-0.8 µm and 0.8-1.1 µm, in which the different cloud systems are represented with a varying degree of distinctness.

Introduction

It is the purpose of this paper to show by a couple of examples the usefulness of the ERTS pictures in the investigation of cloud structures and especially of certain meso-scale structures that have up till now been fairly reluctant to analysis. The report is an abstract of a larger paper on the subject-matter published in Swedish (Mattsson 1973). For considerations of space has been omitted among other things one section dealing with patterns and structures of cirriform clouds. The other sections have been heavily abbreviated.

Patterns of cumuliform clouds

Cumuliform clouds are often arranged either according to cellular or banded patterns. These patterns which are often visible in satellite pictures, are conditioned by convection and can be strongly affected by wind conditions.

A cellular pattern is caused by cellular convection on a mesoscale within the lowest layers of the atmosphere. The thickness of the convective layer and the conditions of stability next above this are considered to be determinative to the shape of the pattern by several researchers. Well-constructed cellular patterns easily come into existence over thermically relatively homogeneous surfaces, e.g.a sea area, especially when the winds in the area are weak (high pressure). (Barrett 1967.) Besides, the vertical wind shear ought to be small.

The cellular patterns may display two types — open and closed (Anderson & al. 1966). The open ones consist of irregular polygons with cloud-free centres, and the closed ones of more symmetric cloud elements surrounded by cloud-free belts. The former type is considered to appear when the heating from below is strong, the latter when the heating from below is weak. The cloud-covered parts of the patterns mark areas with rising air and the cloud-free ones indicate zones of subsiding air. Several of the cellular patterns have not been satisfactorily explained as yet.

The banded patterns often appear within relatively equally thick and widely extended air layers which are superimposed by stable air. When the convection reaches the stable layer and a strong vertical wind shear is at work, the thermals and the clouds, if any, are arranged in long, mutually parallel bands or streets. These are parallel to the direction of the wind shear in the convective layer within which the clouds are situated. Between the cloud bands there are weak downward air currents.

If the convection is powerful enough to penetrate the stable layer, a more chaotic pattern is established from time to time. The banded pattern is also destroyed when the clouds are spread out as a stratocumulus sheet at the stable layer. Therefore, the banded patterns become especially common and permanent within areas of subsidence because great evaporation counteracts the growth and spreading of the clouds in these areas (Scorer 1972).

Banded patterns display certain geographical preference — they are, for instance, the normal convection form in Finland and northern Scandinavia — but are essentially dynamically produced and, therefore, they can be formed independent of orography or the local thermal conditions of the ground surface (Stringer 1972). Narrow but permanent cloud streets, however, are not seldom built up in association with particularly effective convection-releasing landforms, e.g. isolated hills. The banded patterns as well as the cellular patterns fall into several different categories whose character is not yet fully explained.

Fig. 1 shows the result of great convective activity over Scania. In the west there were well-developed streets of Cumulus mediocris and congestus. In the east the cloud growth was greater with bulky Cumulus congestus with expansion of the clouds into a more continuous cover (closed cellular pattern). On the whole, the cloud streets were parallel to the east-north-east surface wind that was blowing at the rate of 5 - 10 m/sec over the landscape in connection with a high pressure over the British Isles, North Sea and South Scandinavia. In the higher layers, too, there were winds blowing from approximately ENE. Accordingly, the wind and shear directions were at large identical. It can not be entirely left out of consideration that the dense cloud shade between the cloud streets gave rise to horizontal temperature differences in the landscape, which combined to preserve the banded structure.

Fig. 2 shows a low-situated banded pattern of stratocumulus and cumulus over the sea between Gotland and Gotska Sandön. In connection with a high pressure over Scandinavia surface winds from the NNE (5 m/sec) were blowing in the area. Even the first, tiny cloud elements of the structure (topmost) were arranged into streets which indicates that a banded pattern had been established in the current already below the condensation level.

Fig. 3 covers a sea stretch 50 - 100 km to the north of Gotska Sandön. The date of recording was the same as that of fig. 2. A unique pattern of rounded cloud-masses encircled by cloud-free broad belts is visible in the picture. The central cloud-masses (cumulus and stratocumulus) marked zones with rising air, and the cloud-free belts, probably, areas of subsiding air. The structure, although somewhat sparse, belonged to the type of closed cellular pattern.

Patterns and structures of stratiform and strato-cumuliform clouds

Extended layers of fog and stratus are often clearly visible in aerial and satellite pictures. The upper surface is usually very bright, even and uniform, although, at times, it can display a fine band or wave structure, transversal to the wind. This structure may be caused by strong vertical wind shear or by convection owing to loss of heat from the cloud top by long wave radiation, possibly in conjunction with heating from below. The convection may also give to the upper surface of the fog or clouds a lumpy structure. Less often fog or stratus have a banded pattern that is longitudinal to the shear direction. In certain cases these cloud structures might be so conspicuous that the designation stratocumulus is more adequate than stratus.

The edges of the fog and stratus-layers are here and there very sharp and not seldom they follow coast lines, mountain slopes and other orographic boundaries.

Fig. 4 shows an extensive fog layer over Öland and eastern Småland (combined advection and radiation fog within a high-pressure area). The dark, lacunal patches were shadows from higher located altocumulus sheets (4900 m above the fog; estimated on the basis of the shadows). Some of these cloud flakes were furnished with thinly delineated outgrowths (high ice-clouds; cirrocumulus). The recurrence of the altocumuli in a wave or banded pattern in the top right-hand corner of the picture should also be noted. The distance between the bands amounted to a whole 13 km.

Fig. 5 shows a fog and stratus area over Kattegat (high-pressure conditions). Most part of the layer was characterized by a Bénard cell pattern, which was probably convectively conditioned. Moreover there was a fine, transversal wave structure whose smallest elements visible in the film had a wavelength of ca 400 m. This watering is too fine to appear in the imagery of the common weather satellites. In the eastern parts of the layer there was a tendency to disintegration followed by traces of longitudinal bands and a distinct, in this case real lacunal formation. The latter may have been caused by cellular, downward or upward convection that carried cloud-free air through the strati. Noteworthy are also the very sharp edges of the fog layer at some places, which edges on the whole parallel the Danish coast.

The continuous cloud area in fig. 6 is a stratocumulus cover. It is obvious that the cloud sheet, as for its structure, is reminiscent of fog and strati. Without information from ground-based observers it can be hard to distinguish between fog, stratus and stratocumulus in satellite imagery.

A condensation trail from an aeroplane can also be seen on the picture. The trail is tapering upwards on the picture, which indicates that the plane was flying in this direction. At the bottom of the picture the trail has expanded to a cirrus sheet, 6 km in the breadth, owing to the wind shear. In this area cirri occurred (the "haze" of the picture), which indicates that the air was here supersaturated with respect to ice (Pedgley 1962). This state of things which is typical before a warm front (in agreement with weather conditions), must be considered to favour continued growth of trail.

In the film one can clearly watch the shadow of the trail on the ground and on the upper side of the stratocumulus cover. (Less clearly in the reproduced picture) If the altitude of the plane has been permanent when its shadow passed the stratocumulus edge, one can calculate the altitude of the plane (7100 m) and the altitude to the upper side of the stratocumulus layer (1070 m) with the aid of the sun's altitude and azimuth and the distance between the trail and its shadow in the picture.

Choice of channel in studies of clouds with pictures from ERTS-1

The experience available after this investigation speaks in favour of the fact that the channels MSS 5 or 6, sometimes even 7 should be chosen when studying patterns of cumuliform clouds. Within these three spectral areas cloud shadows are very visible on the ground, which makes the cloud pattern in the picture to be reproduced distinctly and with good relief effect. Water surfaces are pictured dark in the three bands and therefore such cloud patterns e.g. over the sea also appear distinctly within the said bands.

With respect to stratiform and strato-cumuliform clouds the choice should be between MSS 5 and 7. The fine structures of these clouds are delineated especially distinctly within these two bands.

Finally, as regards the cirriform clouds, these are most distinct in MSS 4. In MSS 6 and 7 these clouds become strikingly transparent and disappear partly in the pictures (cf Lyons and Pease 1973). Only their more compact structures stand out against the darker background of the earth's surface. When studying these compact structures more closely, it may, however, be appropriate to choose MSS 7. Imagery from different channels may be used for interesting analyses of the glaciation in the upper portions of the cumulonimbus clouds.

Shadows of condensation trails are especially distinctly outlined within MSS 7.

Conclusion

With ERTS-1 cloud physicists and investigators into the meso-systems of the atmosphere have got a superior instrument. As has been shown or hinted at in this report the ERTS pictures are particularly fitted to investigations of the more small-scale patterns and detailed structures of the cloud systems. In combination with cloud altitude determinations that are often easy to make in the pictures, such studies can give among other things valuable knowledge of the morphology and dynamics of the clouds and of the wind and temperature field within the cloud area. Here are considered among other things wind shear, thermal wind, stability conditions, heating and frictional effects. The knowledge of the thermal wind can e.g. be used in the location of warm and cold air and at the judgement of the advection conditions in these air masses. The ERTS pictures can also be used for the location of concentrations of condensation trails and in the study of the development of these artificial cirrus clouds and in studies of fog. These two applications make the pictures useful also in investigations on man's impact on the atmospheric environment and in different planning activities.

The ERTS pictures with their excellent resolution and distribution over different spectral bands can be looked upon as a new generation of satellite pictures. The guides to cloud interpretation in satellite pictures that have been used up till now (Conover 1962) are sure to be subjected to comprehensive amplifications in order to make them fit also to this new imagery.

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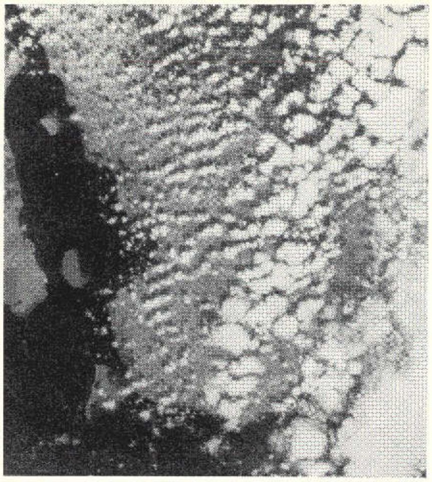
SMHI:s Bulletin- och Arbetskartor.



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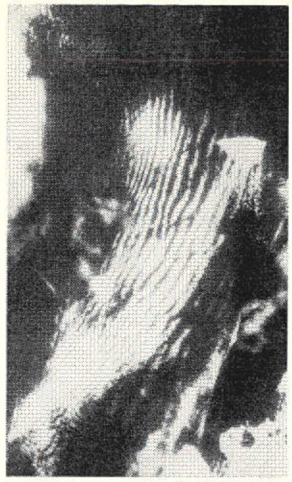

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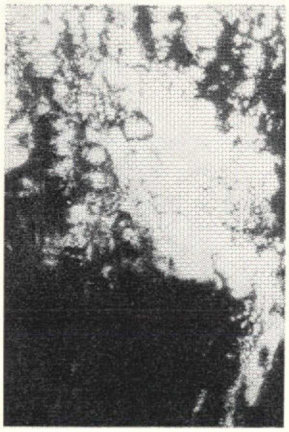

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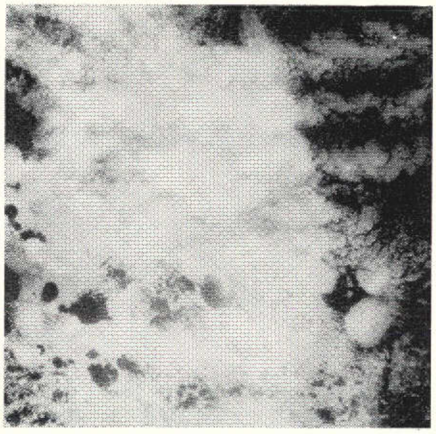

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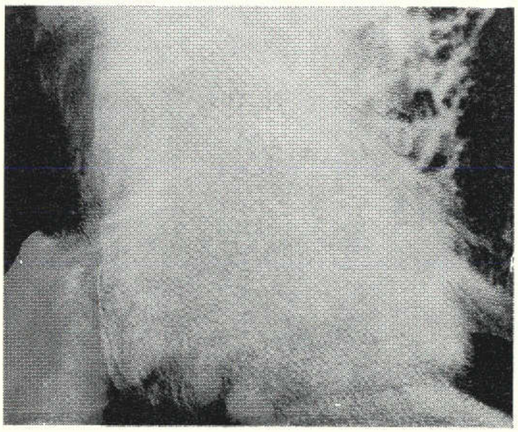

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Figs 1 - 6. ERTS pictures of clouds. 1: Sept. 1, 1972, 9.41 GMT, MSS 5, no. 1040, 1:1 580 000. 2 and 3: Aug. 30, 1972, 9.29 GMT, MSS 6, no. 1038, 1:1 430 000. 4: Oct. 6, 1972, 9.35 GMT, MSS 5, no. 1075, 1:1 900 000. 5: Oct. 9, 1972, 9.52 GMT, MSS 5, no. 1078, 1:1 790 000. 6: Febr. 10, 1973, 9.41 GMT, MSS 7, no. 1202, 1:1 950 000.

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
1038-09290-6				Banded cloud pattern Cellular cloud pattern Cloud street Cumulus Stratocumulus
1040-09412-5				Cellular cloud pattern Cloud shade Cloud street Convection Cumulus
1075-09352-5				Altocumulus Banded cloud pattern Cirrocumulus Fog
1078-09523-7				Bénard cell pattern Convection Fog Stratus
1202-09415-7				Condensation trail Stratocumulus Wind shear

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STUDIES OF CLOUD FORMATION IN COASTAL AREAS BY MEANS OF ERTS-1 IMAGERY

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Abstract

Images from the ERTS-1 satellite make it possible to study details in cloud patterns and such cloud formations as are due to mesometeorological effects. This paper concerns some special cloud patterns in coastal regions.

Introduction

Photographs taken by weather satellites, such as Tiros and Nimbus, have given us an opportunity to study cloud covers and cloud patterns, but the image scale allows only of the identification of bigger, separate clouds, such as cumulus congesteus and cumulonimbus (BARRET 1970). The weather satellites also yield information about the ground surface, which has aroused interest in developing satellites with special equipment for ground detection. On the other hand, it has now appeared that the ERTS-1 satellite, which is especially constructed for earth-resource studies, yield information about cloud formation which has not been available earlier.

Clouds in Coastal Areas of Southern Sweden

Images from the ERTS-1 MSS system admit of the identification of objects less than 100 m long (SVENSSON 1973). In identifying clouds, there is a need for bigger units, since they have no sharp contours and since there are sometimes problems in distinguishing them from the ground surface.

Fig. 1 shows parts of images from the western coast of Sweden, south of Gothenburg, recorded by the satellite multispectral scanner on the 2nd of September, 1973. In the upper left-hand corner of the images runs the Götaälv River, in which harbours in Gothenburg appear. The Onsala peninsula will be noted in the lower left-hand corner.

There is a rather large difference in the recording of clouds at the different wave-length intervals. In MSS 4 (0.5–0.6 um), clouds appear distinctly (Fig. 1 a). This is also true of cirrus clouds, which means that information from the ground surface may be restricted. Compared with the other wave-length interval used, it is generally easier to identify cumulus clouds in images from MSS 5 (0.6–0.7 um, Fig. 1 b). Even cirrus clouds are clearly visualized but are not so restricted as regards ground information as in MSS 4. The images recorded in near infra-red, MSS 6 (0.7–0.8 um) and MSS 7 (0.8–1.1 um), show such a light ground surface that the detection of cumulus clouds over land is restricted. It is hard to identify cirrus clouds in MSS 6 (Fig. 1 c), and they almost completely disappear in MSS 7 (Fig. 1 d).

The existing cumulus cloud are aligned with short cloud streets (Fig. 1). These cloud streets are generated at some distance inside the coastline and follow the ridges in the terrain. For example, there are no clouds over Lake Lygnern, but there are cloud formations over the hilly areas on both sides of the lake. This is true also of the valley that ranges from the north-eastern part of the lake. There are no cloud formations over the valley from Kungsbacka northwards, but over the Onsala peninsula and further to the north there are frequent formations of cumulus clouds, mostly orientated in two cloud streets. With few exceptions, the existing cumulus clouds are formed over relatively hilly regions close to the coastline. At some distance from the coastline, the moisture content of the air is too low for condensation.

The billow-shaped clouds close to the coastline in the lower part of the images are part of a cover of altocumulus over the Kattegat.

Images from satellites of the Tiros and Nimbus series have shown that cumulonimbus clouds are almost always orientated in lines or streets, parallel to the wind direction. Ground and aircraft observations show that also cumulus clouds are frequently aligned with cloud streets, but the necessary survey to determine the cloud pattern is available only in images from ERTS-1.

The direction and extension of cloud streets yield information on the prevailing weather situation, especially concerning horizontal and vertical air movement above the condensation level. The determination of the direction of cloud streets in coastal regions is a simple method of mapping wind directions.

On the 30th of August, 1972, a chiefly north-easterly wind generated cloud streets over the island of Gotland in the Baltic (Fig. 2). The picture is a part of a satellite image recorded in MSS 5. In the upper part of the picture, there is a broad cloud street just across the island. To the south, there are 15 narrow but distinct cloud streets. The clouds are generated approximately 10 km inside the coastline, but careful interpretation of the image shows that small cumulus clouds exist closer to the coastline. The cloud streets widen towards the south-west, but at the same time they are less numerous. Also over the point of land in the south, Storsudret, there are some small cloud streets. In the south and south-west, there is a dense cloud cover. In the easternmost part, Östergarn, it is possible to observe a cloud street over the sea, but it has been generated over the land.

In this situation, an extensive cloud sheet covers the island of Öland, but it is possible to note that the wind direction was more northerly than over Gotland.

A similar weather situation to that demonstrated in the previous example produced cloud formations over a part of the Swedish Baltic coast from Landsort to Västervik. The image was recorded on the 31st of August, 1972 (Fig. 3). In the central part of the picture, cloud streets are generated by an easterly wind, but there is a tendency to a wind shift towards the south when the wind comes from the north-east and the formation of cloud starts close to the coastline. This tendency is more marked in an image covering the coastal region more to the south. This wind shifts more to the north-east and over the island of Öland it is possible to detect wind directions from north-north-east to north. It is also possible to observe wind directions from the north, north of the area covered by Fig. 3 and 50-100 km inside the coastline.

On this occasion the cloud streets change into rather large, non-organized cumuli and cumulonimbus clouds towards the west.

Situations with off-shore winds are generally not accompanied by any characteristic cloud formations in coastal areas. If an off-shore wind is combined with a sea breeze, a special situation may arise. An updraft in the air strengthens the convective cloud formation. Such a wind situation existed in the south-eastern part of Sweden on the 15th of June, 1973. The image from ERTS-1 covers the coastal area between Västervik and Kalmar (Fig. 4). The northern and middle parts of the island of Öland come into view in the lower right-hand corner of the picture. The general wind direction over this area was from the north-west and the wind force was decreasing. The weather situation was characterized by fair weather at a distance from the coastline exceeding 50 km. Towards the coast, the formation of cumulus clouds increases and the individual clouds grow bigger. The big clouds close to the coastline also have fibrous structures, which indicate that they are cumulonimbus clouds. Precipitation data from the day in question show, with one exception, that only weather stations close to the coastline concerned reported rainfall, but in small amounts. Thus, the Västervik station reported 3 mm, Kalmar 2 mm, and Ölands södra udde 2 mm. No precipitation was reported from Ölands norra udde.

When the geotrophic wind is blowing from land to water for the first few hours after sunrise, the heated land air moves in the direction of the geotrophic wind, pushing back the cool sea air (MUNN 1966). If a sufficient pressure differential develops, the sea breeze moves towards the shore, undercutting the land air and developing the characteristics of a macroscale cold front. Similar effects of convergent air near the coastline have previously been discussed by the present author (LINDQUIST 1973). In this case, it is not possible to prove that rising air in connection with a sea-breeze system can result in the formation of cumulonimbus clouds generated from big cumulus clouds.

Conclusions

It has proved possible to study even details in cloud patterns and such cloud formations as are due to mesometeorological effects. The cloud pattern yields more information about the weather situation at the time of recording. The mesometeorological effects observed are in the increased formation of clouds over urban areas on some occasions and some special cloud patterns close to the coastline. The most adequate channels for cloud studies are MSS 4 and 5.

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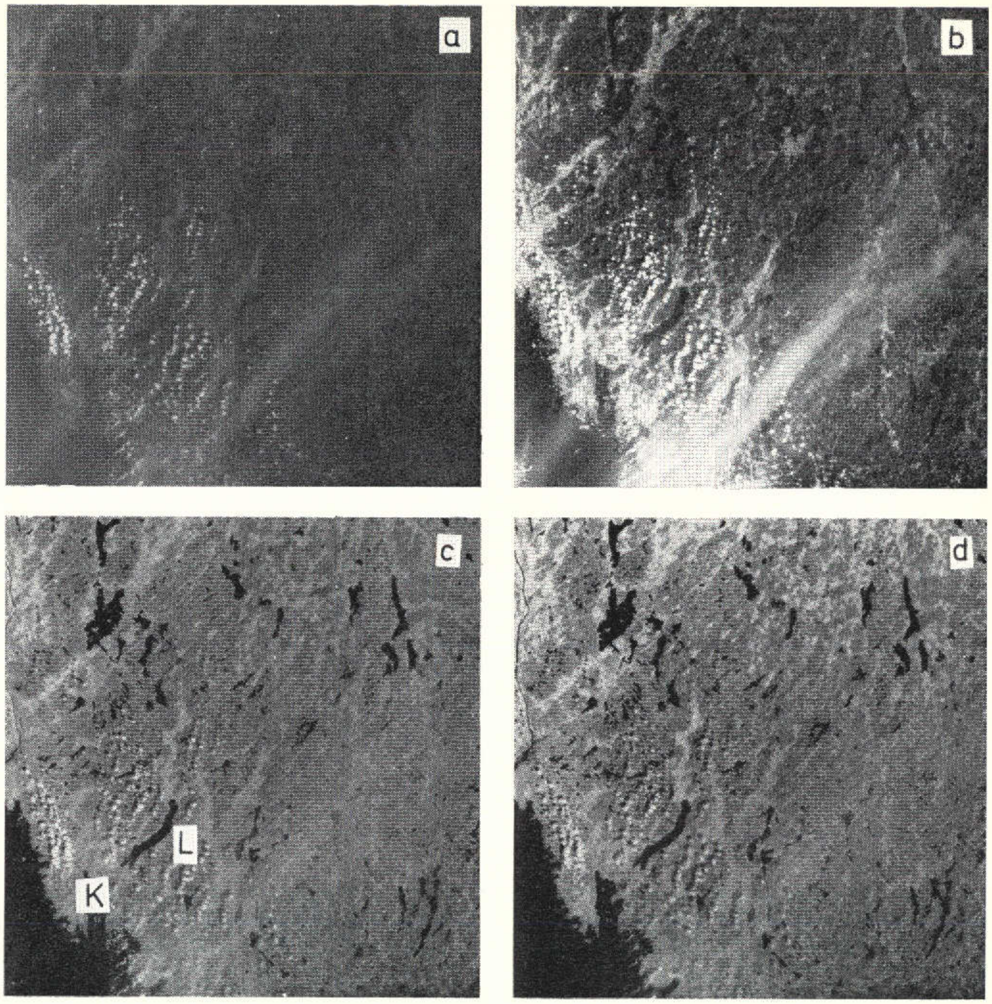

Fig. 1. Parts of images from the western coast of Sweden south of Gothenburg, recorded by ERTS-1 on the 2nd of September, 1973. (a) MSS 4 (0.5–0.6 µm), (b) MSS 5 (0.6–0.7 µm), (c) MSS 6 (0.7–0.8 µm), (d) MSS 7 (0.8–1 1 µm). The existing cumulus clouds are aligned with short cloud streets. Cirrus clouds are clearly visualized in MSS 4 and 5. K = Kungsbacka. L = Lake Lygnern.

Fig. 2. A chiefly northeasterly wind generated cloud streets over the island of Gotland in the Baltic on the 30th of August, 1972. MSS 5.

Fig. 3. Cloud formations over a part of the Swedish Baltic coast from Landsort to Västervik. The image was recorded on the 31st of August, 1972. MSS 6.

Fig. 4. Image from ERTS-1 covering the coastal area between Västervik and Kalmar in the south-eastern part of Sweden. An off-shore wind is combined with a sea breeze. Big clouds close to the coastline have fibrous structures, which indicate that they are cumulonimbus clouds. A MSS 5 recording on the 15th of June, 1973.

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1041-09464-5				Cirrus Cumulus
1041-09464-6				Cirrus Cumulus
1041-09464-7				Cirrus Cumulus
1038-09293-5				Cloud street
1327-09355-5				Cloud street Cumulonimbus Cumulus
1039-09345-6				Cumulonimbus Cumulus Sea breeze

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BREAK UP OF LAKE ICE OBSERVED IN ERTS-1 IMAGES FROM SOUTH-WESTERN SWEDEN

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Abstract

ERTS images are analysed against the background of the existing conventional survey of the break up of lake ice in Sweden. The usefulness of satellite imagery in getting a synoptic view of the ice situation and in studying the break up process in detail is discussed. The various spectral bands and their combination provide information on ice quality.

Introduction

Observation of freeze up and break up of the ice is part of the routine for weather stations in northern countries. These changes in the status of watercourses are of climatic significance as a seasonal phenomenon, and may also be of direct practical importance. In many coastal and inland waters freeze up and break up result in changes in the communication system. The run off in river and reservoirs may be influenced to differing degrees by snow and ice conditions.

The weather satellites have become a very valuable tool for mapping of snow cover and sea ice (BARNES and BOWLEY 1968 and BARNES 1969). Every week throughout the year a map of the snow and ice distribution in the northern hemisphere is produced by National Oceanic and Atmospheric Administration, U.S.A. (SVENSSON 1970). Resolution being limited, the images from the existing weather satellites are, however, of no use for the mapping of ice conditions in lakes, except in the case of very large lakes.

Previous Investigations of the Break Up of Lake Ice in Sweden

There is an abundance of observations on break up of the ice on Swedish waters, gathered by private individuals and by the Meteorological and Hydrological Institute of Sweden. Such data were discussed by HILDEBRANDSSON (1872) and by ERIKSSON (1918 and 1920). Later (1967) MOBERG studied the period 1911/12 – 1960/61, using more extensive observation material. It is in the nature of the problem that in a country as rich in lakes as Sweden observations must concentrate on a selection. The material also had to be reduced during processing with reference to the length and continuity of the observation periods.

ERIKSSON (1920, pp. 2ff) points out irregularities in the quality of the early material, resulting from the different training of the observers and the concentration on the current problem. A certain subjectivity in interpretation is inevitable, although this could be limited in more recent years by the drafting of instructions and standard definitions of freeze up and break up (MOBERG, 1967, p. 2). There are lacunae in the observations series which meant that these had to be complemented by comparison with other nearby lakes or with temperature values from neighbouring weather stations.

The observation material is distributed over 13 geographical areas and divided into three orders of size: large, > 50.0 km^2, medium, 10.1–50.0 km^2, and small lakes, < 10.0 km^2 (Sweden's three largest lakes, Vänern, Vättern and Mälaren, are not included in this division). The statistical processing resulted in tables, diagrams and maps of significant time factors (ERIKSSON, 1920, and MOBERG, 1967).

There is an impressive observation material and an interesting account available for the 50 year period mentioned. The values may be regarded as standards with which each new observation may be compared for assessment, for instant as regards the relationship to the earliest, latest, or average date of the ice break up in the lake or in the lake district concerned. As in the case of all statistics there is still a need for more and more comprehensive data. Long and complete series for representative lakes allow of evaluations of seasonal changes with climatic significance.

The Break Up in a Swedish Lake District

Figure 1 (part of scene 1239-9475) shows the break up situation when the ERTS passed over the south-western part of the South Swedish highlands on March 19, 1973. There is a differenc of about 350 m between sea level (the Kattegat) and the highest area to the south and west of Lake Vättern (the southernmost part of Lake Vättern protrudes at the top of Fig. 1). Most of the area in-land from the coastal plain is covered by forests. Large peat bogs frequently occur.

The lakes, which are still snow covered, stand out in all the MSS bands against the mostly snow free land. The IR channels are most suitable for discrimination between the ice-free lakes and other terrain surfaces. When selecting a definite band for study of ice break up, the MSS band 6 (0.7-0.8 μm) seems most adequate for a forest lake district as in Fig. 1.

All the lakes in the coastal zone (Fig. 1) were ice-free at the time of recording. Nor had the large lakes in the interior of the area any ice cover. Lake Bolmen, the largest in the area, was ice-free, apart from some small inlets. The mean date for ice break up in this lake is April 7th.

The coastal zone (40-60 km wide) belongs to district nr XII as regards freeze up and ice break up. The interior of the area is part of district nr XIII. The average dates of ice break up in district nr XIII are for small, medium and large lakes, April 10th, April 9th and April 10th. respectively (MOBERG, 1967). These values are means of observations of only a few lakes (3, 4 and 2 respectively).

All the lakes in district nr XII were ice-free when the ERTS passed over on March 19th. The indications of ice remaining in the areas furthest to the west appear in a narrow zone 50-55 km from the coast. Nevertheless even very small lakes within this zone are ice-free but some ice remains locally in marshes. There is a certain amount of local cloud formation.

Confusion with clouds is excluded in the rest of the picture. The ice cover is clearly delimited, by either the outline of the lakes or the contrast with open water.

In the case of the lakes in which ice break up is in progress the extent of open water can be surveyed, and the occurrence of holes in the ice and their dependence on the inlets to, or outflows from, the lake can be evaluated. The ice remains in the northern parts of a number of the elongated lakes.

Some irregularities in ice break up seem to occur in the area. The largest lake in the northern part of the scene (Lake Åsunden) is ice-free, apart from some small areas. In the two lakes (Yttre Åsunden and Sämsjön) immediately to the south, ice break up is far advanced. The lake west of Lake Åsunden (Lake Tolken), on the other hand, is still wholly ice covered. The later break up of the ice on this lake,in relation to the other two lakes of similar size, may be due to a number of causes. Apart from water area, the altitude and the depth are the factors most often discussed. The easiest parameter to calculate is the altitude. In this particular case the still frozen lake is situated some 60 m higher than the other two. Single soundings are not sufficient to determine the influence of depth conditions. Depth charts of the lakes are needed.

The eastern part of Fig. 1 shows three very long, almost parallel lakes (Lake Vidöstern, Lake Flåren and Lake Furen), all of which are almost free of ice. The northern section of Lake Flåren has the most ice. The nearest lake to the north (Lake Hindsen) is an anomaly, being completely frozen. The altitude of this lake (166 m a.s.l.) varies by only 15 m from the almost equally large Lake Furen (151 m a.s.l.).

Within the area of generally frozen smaller lakes north west of the series just mentioned we find the anomaly of two small ice-free lakes. These lakes are of interest in that they form part of a bird reserve. Geographically they belong to an extensive area of marshes. As reagards altitude these lakes resemble neighbouring frozen **lakes**. The reason for their early thaw must be sought in local conditions.

Image Processing

An image of the type shown in Fig. 1 provides an excellent picture of the ice situation in a large area and can be directly used for a survey map. This study used colour-enhanced transparencies (9.5 inch) of MSS band 4, 5 and 6. They also proved to allow of the discrimination of solid ice from what seems to be ice slush (cf. SVENSSON, 1973, Fig. 2).

When analysing the ice cover faint tonal differences can be discerned between the lakes and within one and the same lake. The differences are especially characteristic for the near infrared (MSS band 6 and 7). The lower reflectitivty in the infrared bands seems to be caused by melt water on the ice or by a high water content in the lake's snow cover. Using the colour-enhanced transparencies a combination of MSS band 4 and 7 gives the best discrimination of ice quality.

Images can be generated in appropriate scales from digitalised ERTS data. Fig. 2 represents a computer-generated image of a portion of Fig. 1. This scale allows of detailed analyses of the stage of ice break up even in smaller lakes. In the right-hand margin of Fig. 2 there is a lake in which ice break up has just begun, with formation of two holes (in the eastern and southern part of the lake). On the opposite side of Fig. 2 ice break up may be observed in a chain of small lakes in the valley of the River Nissan.

The ERTS imagery could be regarded as a natural map in which information is stored at the moment of recording. By inspecting and analysing the image the observer is enabled to select the particular data of interest to him. Since the image data are available in digital tape, the analysis of geographical and geological problems could also be entrusted to a computer. A problem such as that of analysing the ice break up in lakes, employing fairly simple spectral variables, could most probably be solved by the use of a computer producing a detailed image or a digital printout in the form of a map.

Conclusions

Considering scale and resolution conditions adequate, satellite data for recording of ice on lakes became available for the first time with the introduction of ERTS imagery.

The break up process in a lake district such as that considered in this paper is clearly visible in all MSS bands. The multispectral data, however, also renders possible the discrimination of ice quality and water content

(MSS band 6 and 7).

The multispectral data provide a rapid and synoptic view of the ice situation. A large number of observations are objectively recorded.

ERTS-1 imagery allows of the selection of representative lakes for continual observation in the field. Anomalous lakes can be discerned.

The snow situation in particular is important for runoff and flood forecasting in the early spring. The runoff could, however, also be influenced by the ice situation in a river system observable in ERTS imagery.

Digital data processing seems to afford an adequate technique for the monitoring and mapping of the break up situation from a large amount of multispectral data.

Being an experiment ERTS-1 indicates the usefulness of satellite data for the observation of the ice situation. An operative satellite with increased observation frequency is required for the solution of the entire problem.

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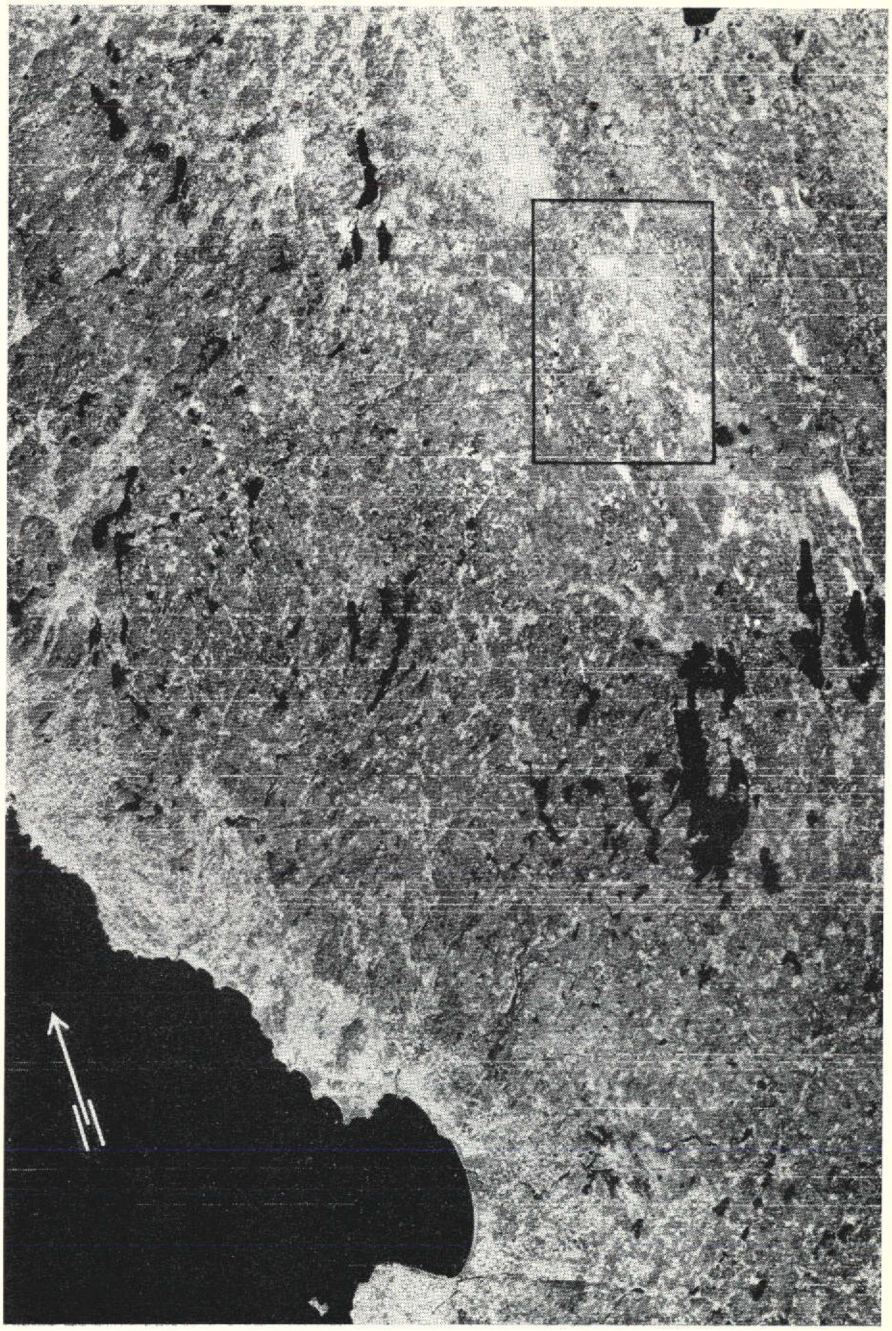

Fig. 1. ERTS-1 imagery (1239-09475-6) of an area of south-western Sweden, recorded on March 19th, 1973. Approx. scale 1:1 milj. (The rectangle marks the location of Fig. 2.)

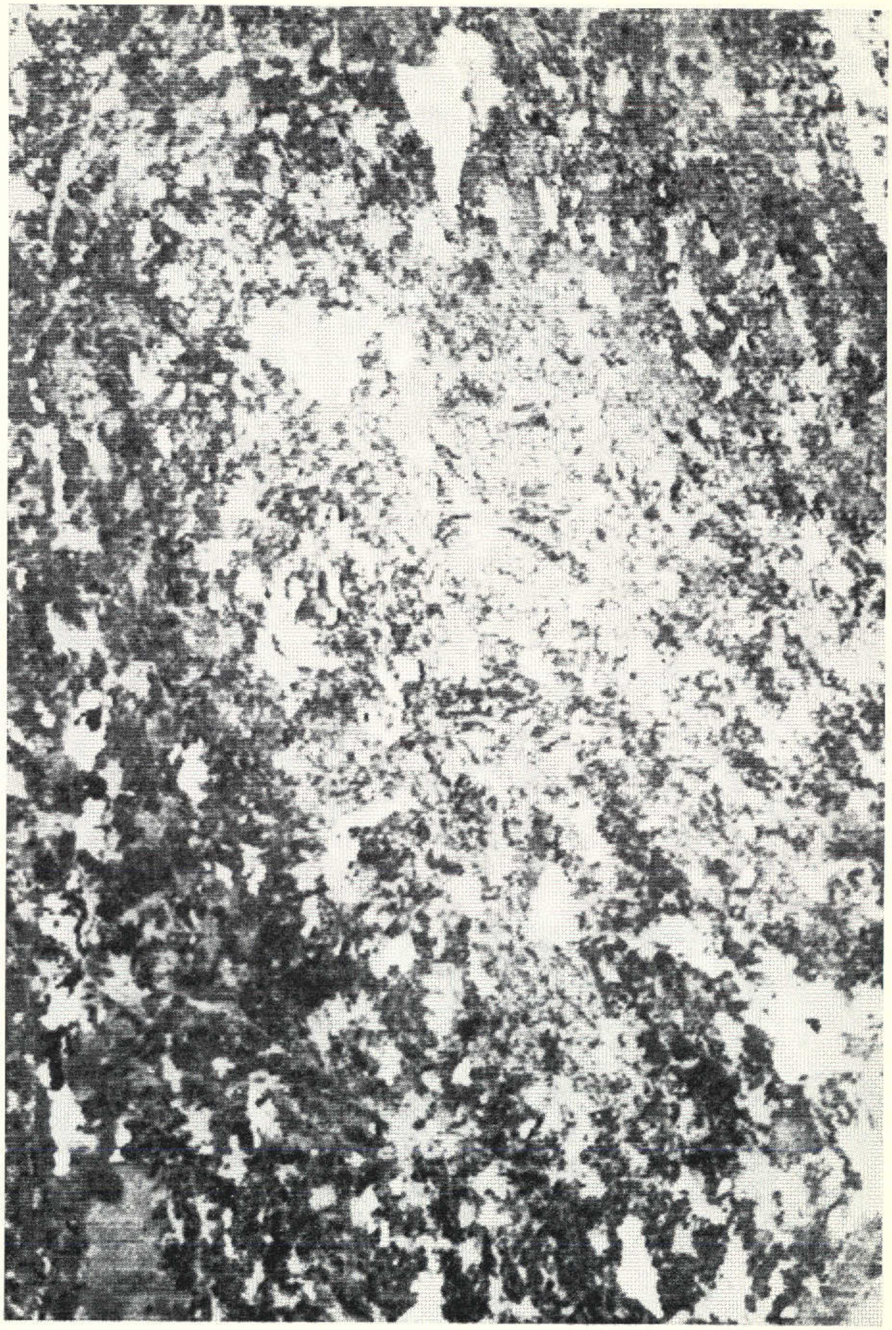

Fig. 2. Computer-generated image of a lake area in Fig. 1.
Approx. scale 1:200 000.

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ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

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ID

DATE January 25th 1974

PRINCIPAL INVESTIGATOR Harald Svensson

GSFC FO 426

ORGANIZATION Department of Physical Geography
University of Lund, Sweden

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
1239-09475-6-7				Ice (lake-) Lake

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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